NASA/CP—1999–209482

Proceedings of the First Annual NRO-OSL/GSFC-ATS Rideshare Conference

William Cutlip, Ed.

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

October 1999

The NASA STI Program Office ... in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the lead center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.
- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.
- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.
- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and mission, often concerned with subjects having substantial public interest.
- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at http://www.sti.nasa.gov/STI-homepage.html
- E-mail your question via the Internet to help@sti.nasa.gov
- Fax your question to the NASA Access Help Desk at (301) 621-0134
- Telephone the NASA Access Help Desk at (301) 621-0390
- Write to:
  NASA Access Help Desk
  NASA Center for AeroSpace Information
  7121 Standard Drive
  Hanover, MD 21076-1320

Available from:

NASA Center for AeroSpace Information
7121 Standard Drive
Hanover, MD 21076-1320
Price Code: A17

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Price Code: A10

Proceedings of the

1st Annual NRO-OSL/GSFC-ATS Rideshare Conference

April 15-16, 1999

FIRST ANNUAL

GODDARD SPACE FLIGHT CENTER – ACCESS TO SPACE GROUP
NATIONAL RECONNAISSANCE OFFICE – OFFICE OF SPACE LAUNCH

RIDESHARE CONFERENCE

Mr. William Cutlip and Mr. Jim Liller
Co-Chairmen

LITTON/TASC FACILITY
DULLES, VIRGINIA

April 15-16, 1999

FIRST ANNUAL GSFC–ATS/NRO–OSL RIDESHARE CONFERENCE

15 Apr 99

8:00	Security	Chip Harbaugh/TASC
8:10	Opening Remarks	Lt Col Arey/NRO/OSL/APD
8:20	Administrative	Jim Liller/NRO
8:30	Agenda	Jim Liller/NRO
8:35	RideShare Catalog	Jim Liller/NRO
8:50	Access To Space Program	Bill Cutlip/GSFC/ATS
9:05	Rapid S/C Development Office (QuickRide)	Jim Adams/GSFC
9:25	Spartan Project Office	Dave Shrewsberry/GSFC
10:10	Break	
10:20	Shuttle Small Payloads Project	Chris Dunker/GSFC
10:40	MightSat Program	Pete Thomas/AFRL
11:00	Spectrum Astro Buses	Scott Yeakel/Spectrum Astro
11:20	Lunch	
12:30	Integrated Space Systems Buses	Phil Smith/ISS
12:50	Athena	Trip Carter/LMA
1:00	Orbital Buses	Regan Howard/Orbital
1:20	Ball Aerospace Buses	Terry Schrepel/Ball Aerospace
1:40	Lockheed Martin Buses	Ed McNamara/LMMS
2:00	Break	
2:10	Orbiting Tech Testbed Initiative	Jim Ritter/NRL
2:20	Swales Bus	Mike Cully/Swales
2:35	TRW Buses	Donald Marshall/TRW
2:55	FAISAT™	Jason O'Neil/Final Analysis
3:15	GEO Bus	Paul Regeon/ONR
3:30	Stanford MicroSat	Bob Twiggs/Stanford University
3:45	Space Transportation Program	Dennis Smith/MSFC
4:05	United Space Alliance	Therese Thrift/USA

16 Apr

8:00	Agenda	Jim Liller/NRO
8:05	Universities Space Research Assoc	Jack Sevier/USRA
8:20	SpaceHab	Truss Bardos/SpaceHab
8:40	NanoSat Deployment Concepts	Steve Huybrechts/AFRL
8:55	SERB/STP	Maj Ward/AQSL
9:15	EELV Secondary P/L Adapter	Capt. Scott Haskett/SMC-TELO
10:00	Break	
10:15	PuckSat	Joe Young/Swales
10:30	Space Maneuver Vehicle	Lt Col Verderame/AFRL
11:15	Coleman Aerospace Vehicle Systems	Frank Krens/Coleman Aerospace
11:30	Lunch	
12:30	Orbital Sub-Orbital Program	Maj Buckley/SMC-TEB
1:00	Sat Threat Warning/Attack Rpt Prog	Lt. Col Hilland/AFRL
1:15	NASA ELV Program/Policy	Albert Sierra/NASA HQ
1:30	Pegasus/Taurus	Ed Morris/Orbital
1:50	Boeing Delta II & EELV	Bill Files/Boeing
2:10	Lockheed Martin EELV	Mike Ragole/Lockheed Martin
2:30	Secondary Payload Broker Discussion	All

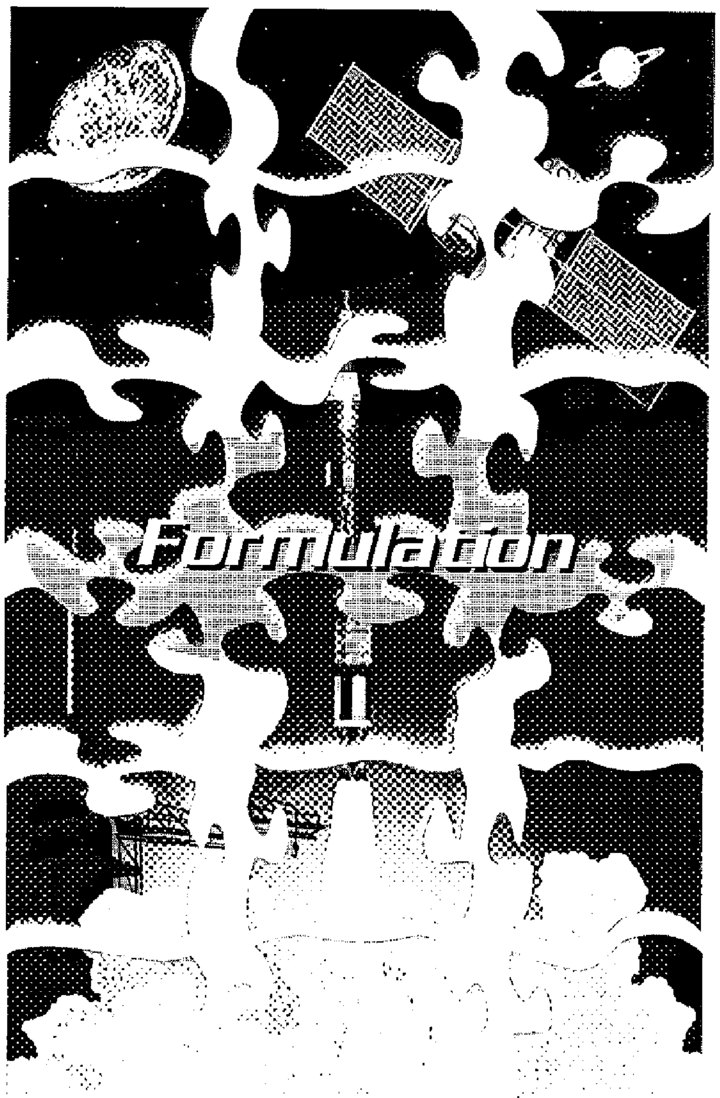

Goddard Space Flight Center
Access To Space
Providing a Ride
to the Future

The ATS Group will support the Goddard Space Flight Center's science and technology community by facilitating frequent, affordable opportunities for access to space and shall be advocates of change to reduce the cost of access. The ATS Group will utilize it's experience and knowledge to provide comprehensive customer support throughout the entire mission cycle. This support will be thorough, innovative, and timely to ensure long-term customer satisfaction.

Goddard Space Flight Center

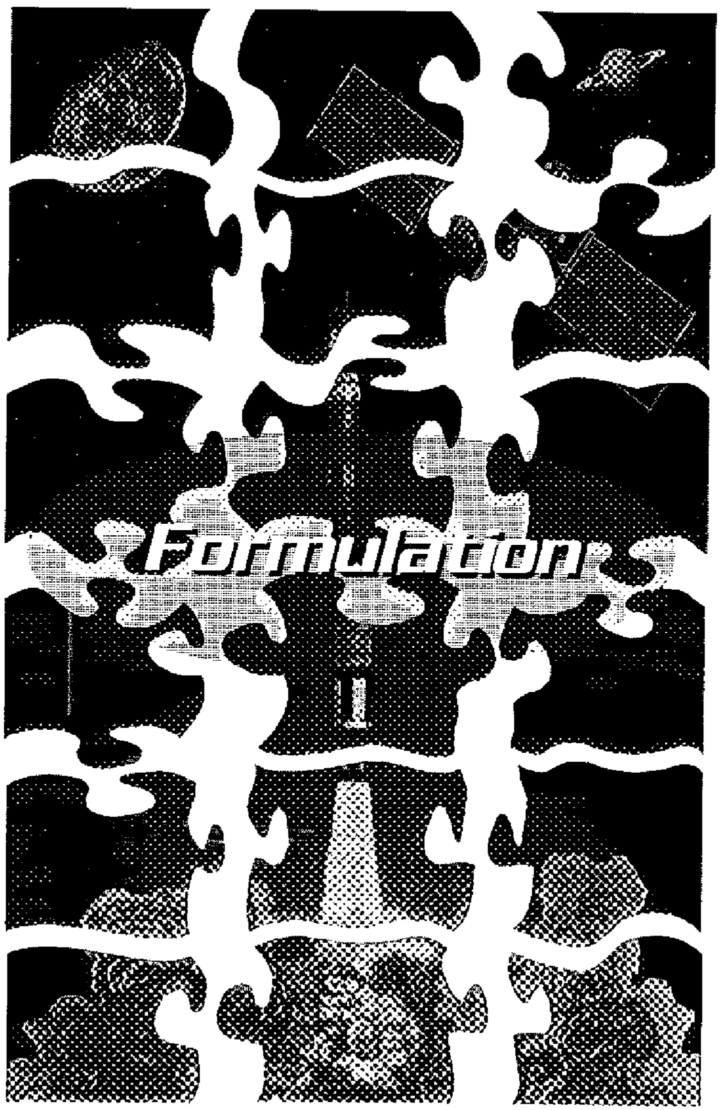
- *Enable discovery through leadership in Earth and space science*
- *Serve the scientific community, inspire the Nation, foster education, and stimulate economic growth*
- *Partner with others to achieve NASA's goals*
- *Be innovative in all that we do*

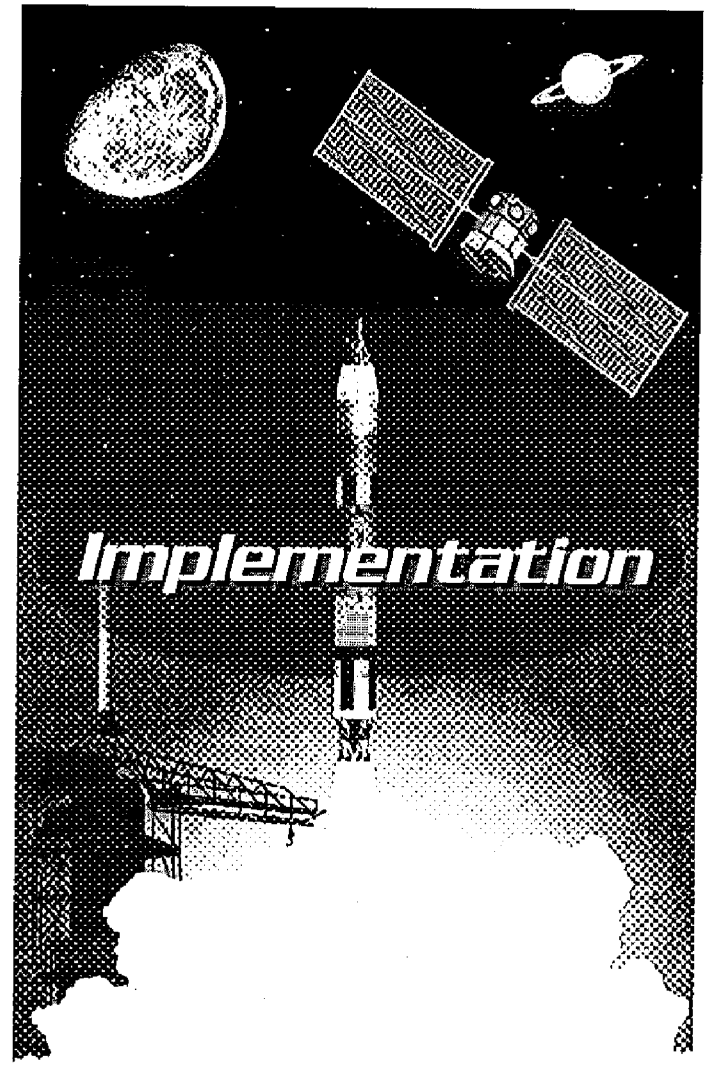
Phases



- *The ATS Agent is responsible for the successful provision of*
  - *Timely, comprehensive information regarding access opportunities*
  - *Technical details specific to each opportunity*
  - *Related cost information*
  - *Supplier specified points-of-contact*

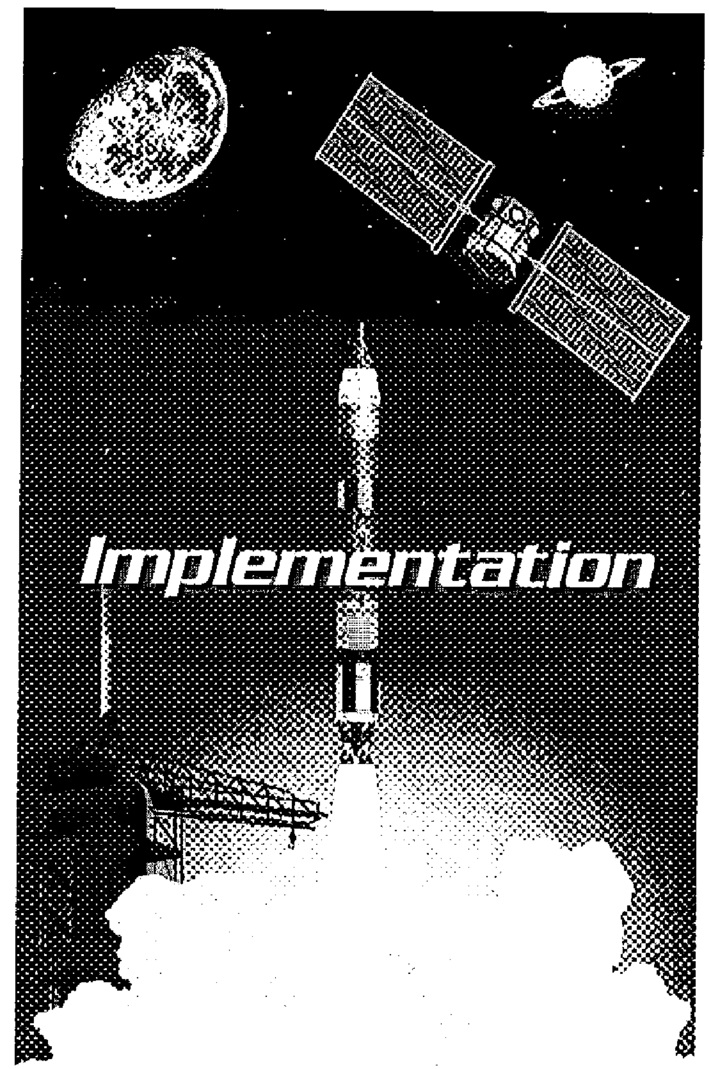
Phases





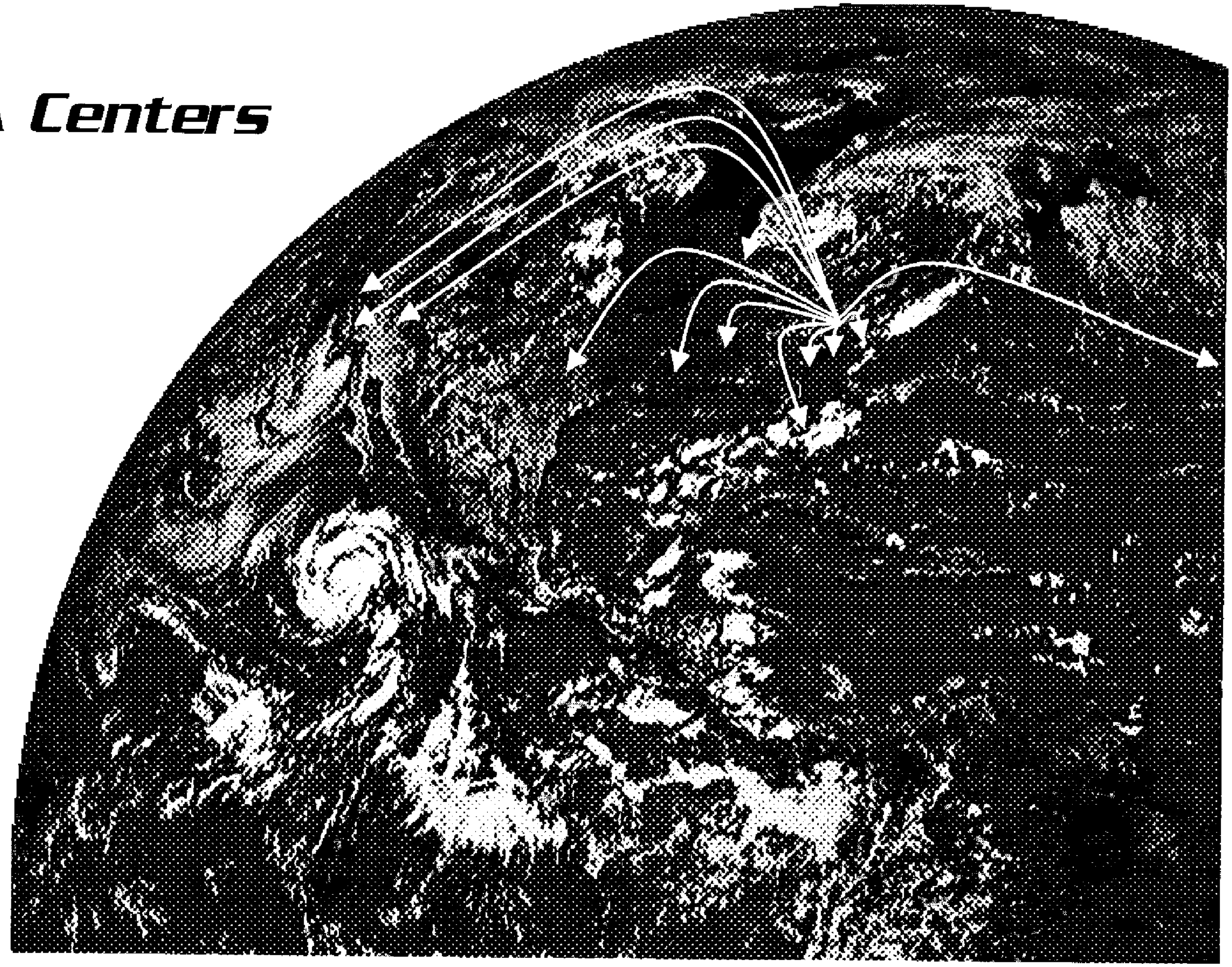
Phases

- *Will be the project's single point of contact for access-related information and questions*
- *Will propose alternate methods, when appropriate, in order to satisfy the customer's needs and requirements*
- *Will continuously evaluate the access mode work performed and procedures used for improvement in efficiency and lowering costs. Will work to prevent requirements to change in scope to the extent that costs and schedules are effected*



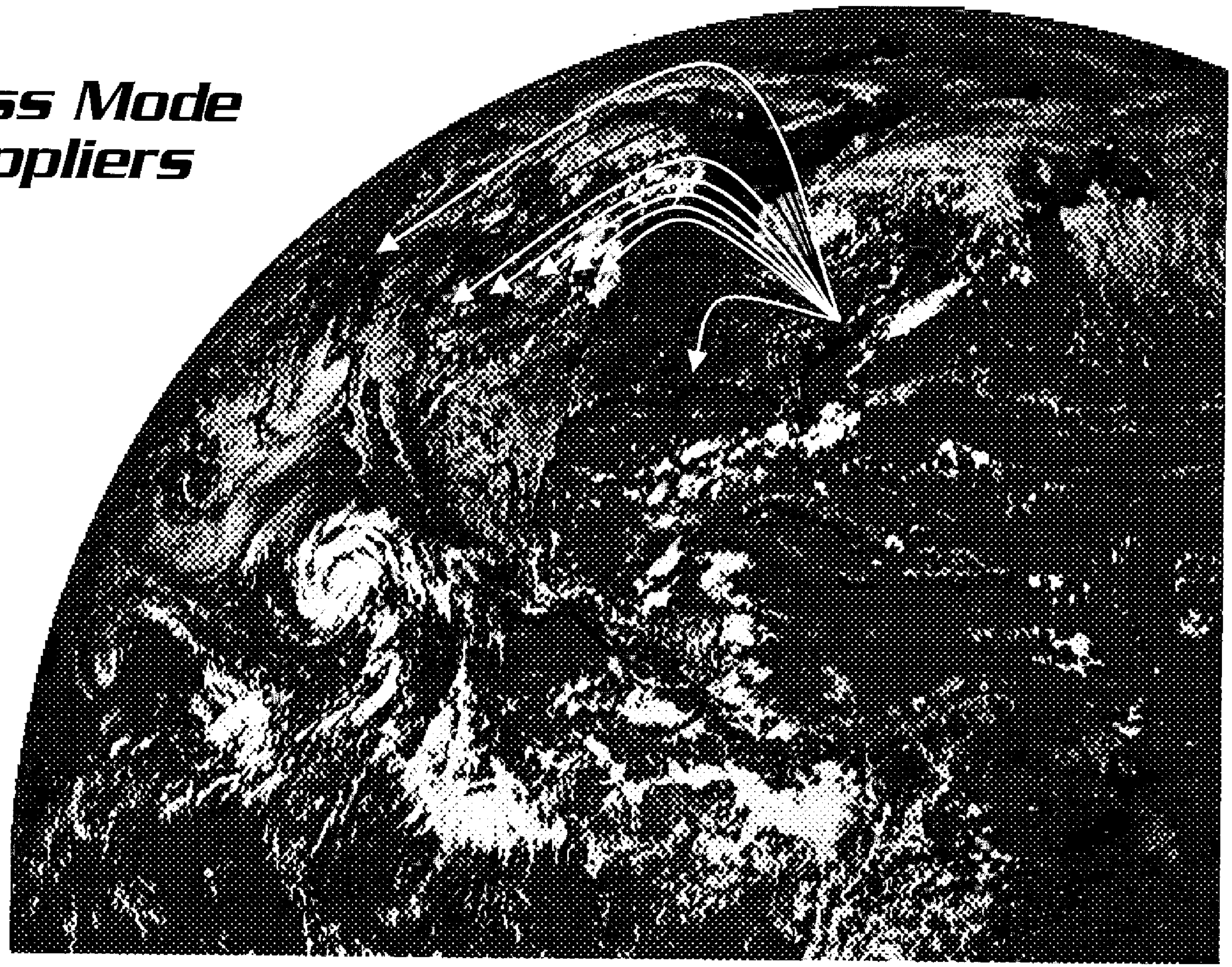
Partnerships

NASA Centers



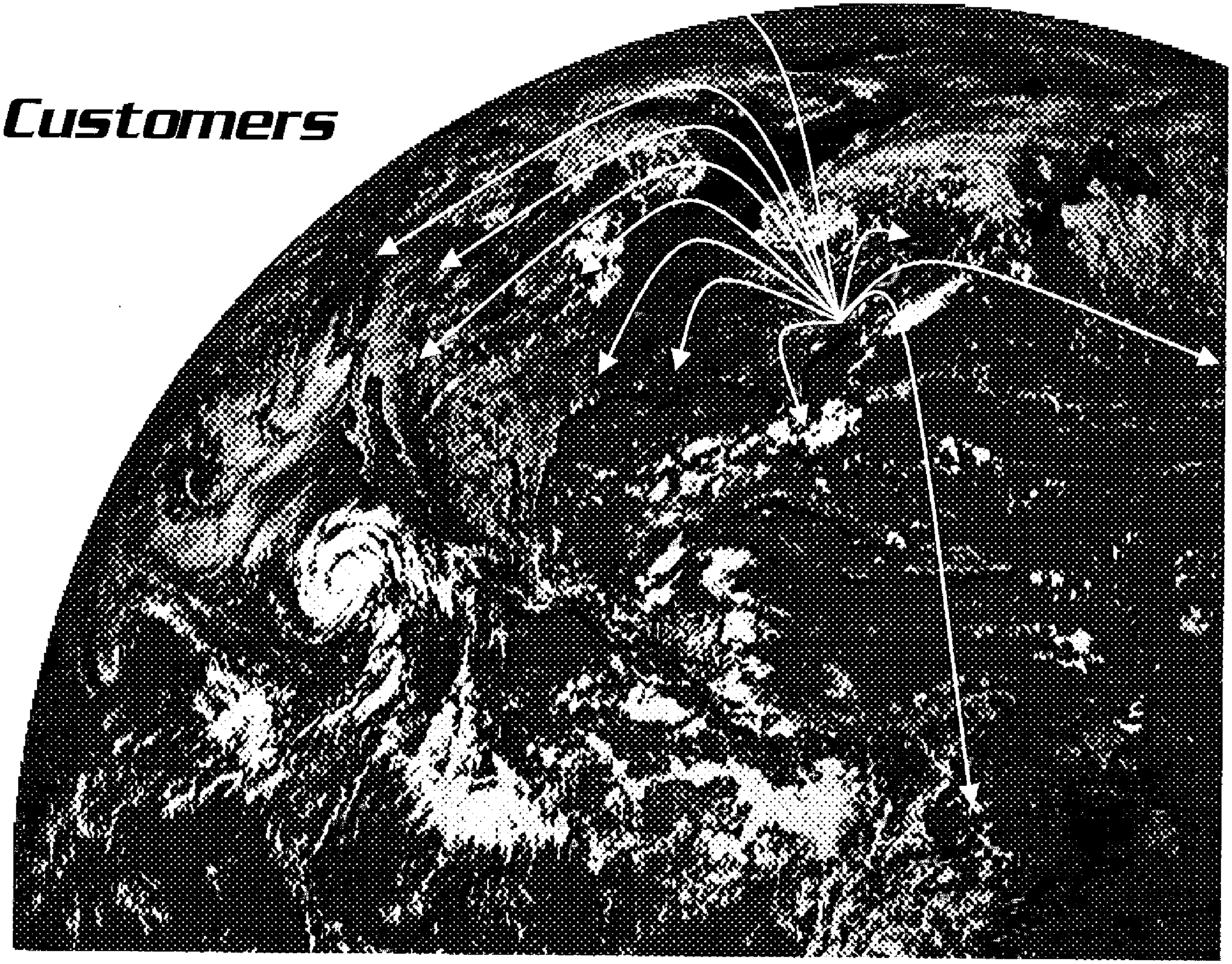
Partnerships

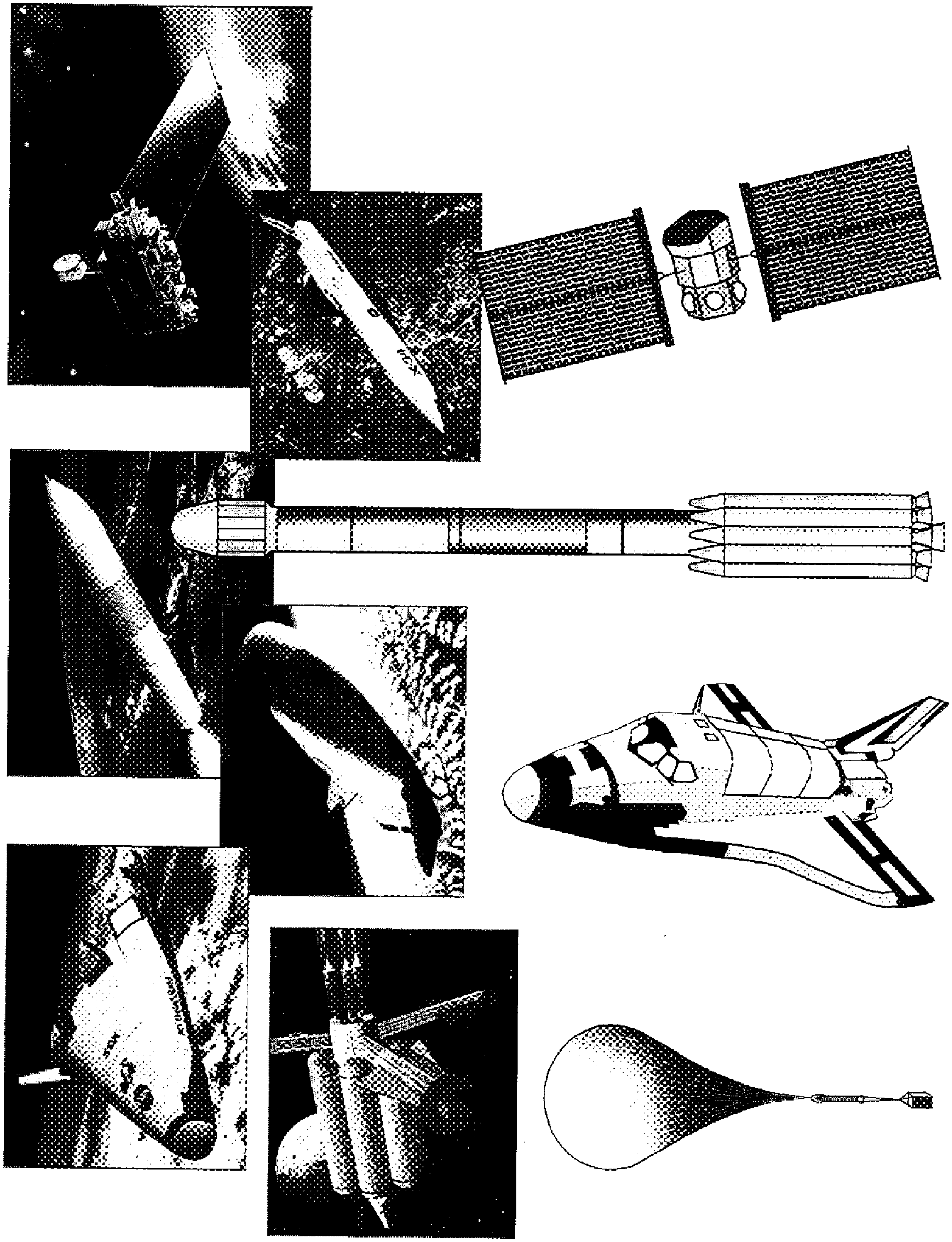
Access Mode Suppliers

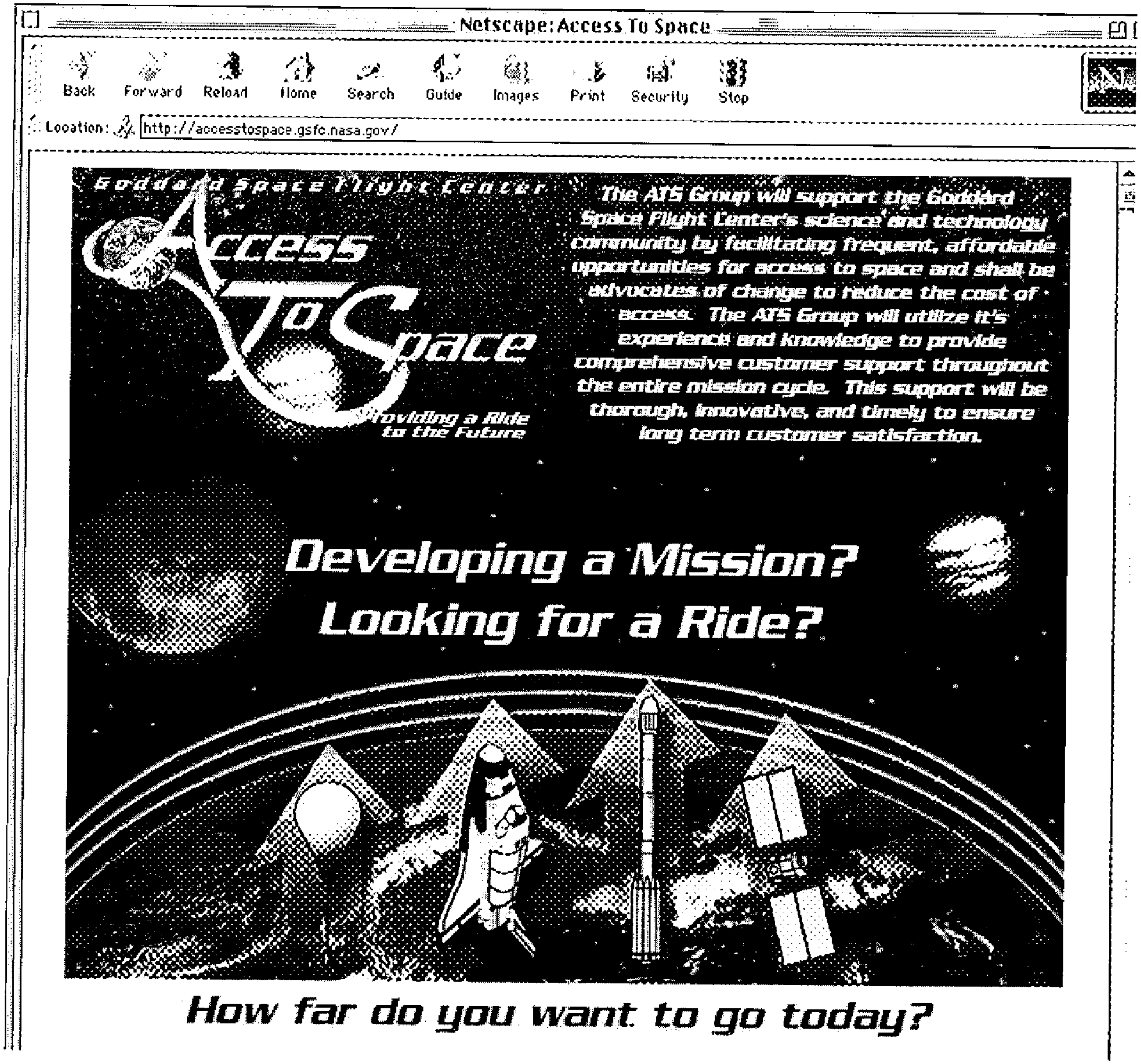


Partnerships

GSFC Customers

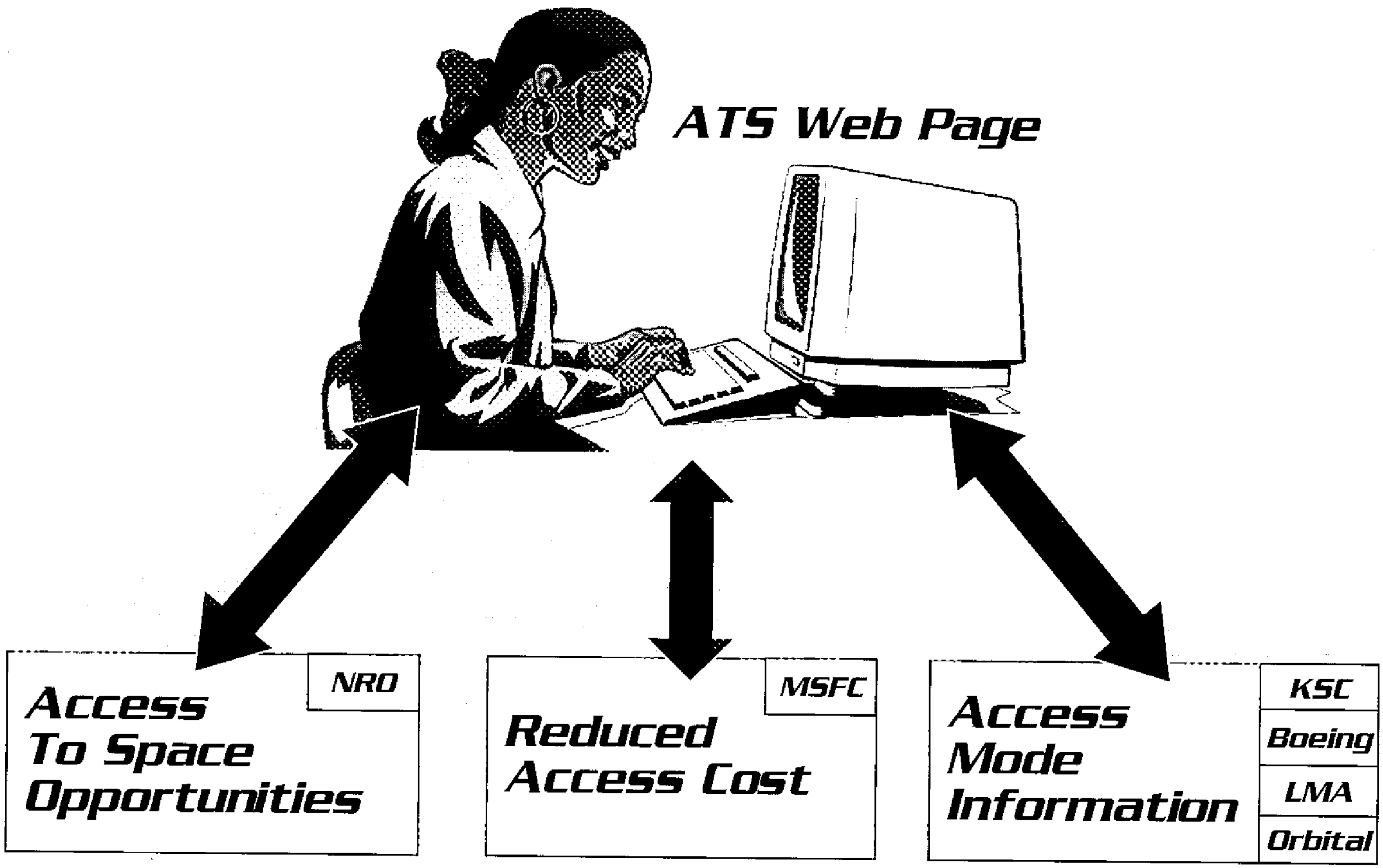


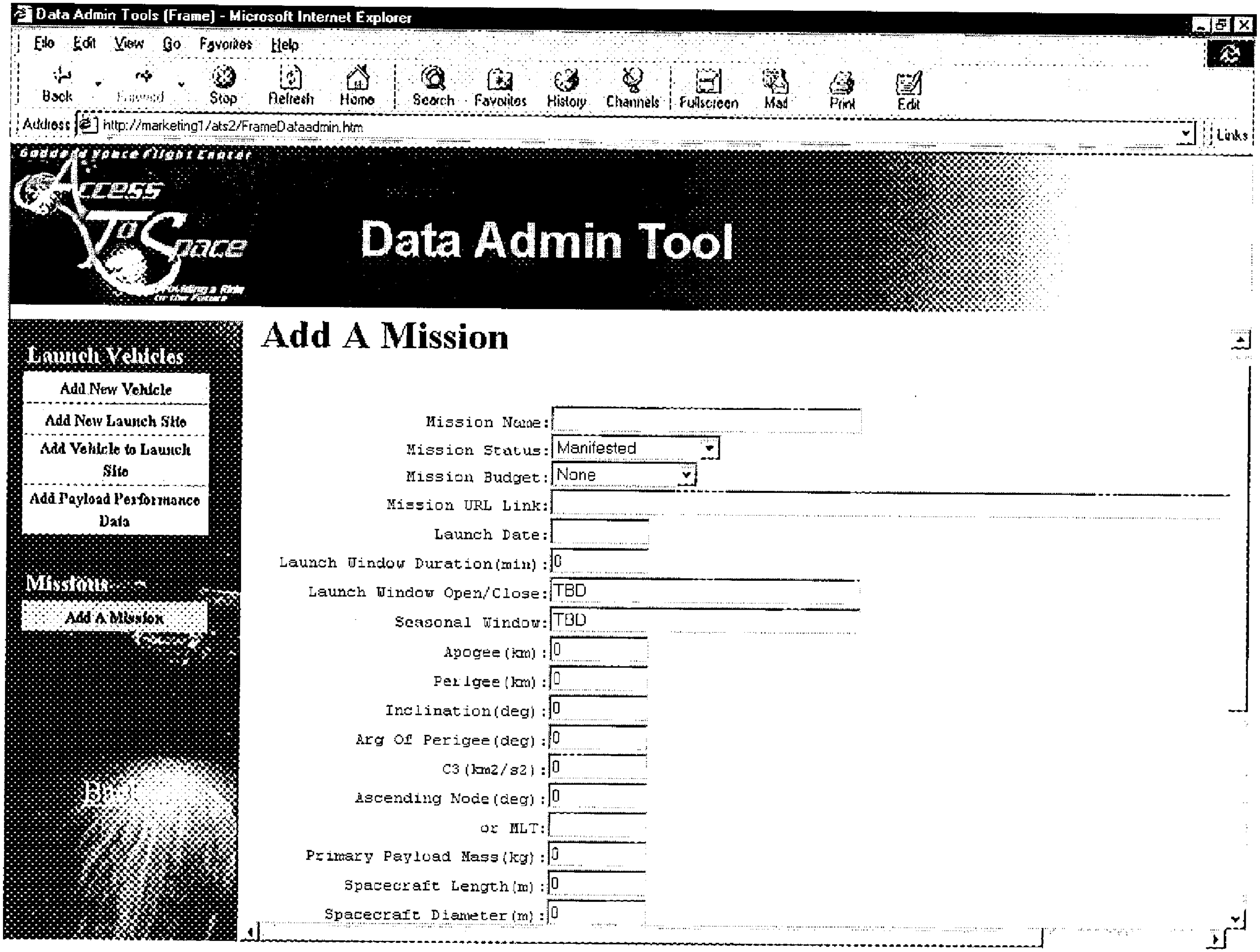



Netscape: Access To Space
Back
Forward
Reload
Home
Search
Guide
Images
Print
Security
Stop
Location: http://accesstospace.gsfc.nasa.gov/
Goddard Space Flight Center
Access To Space
Providing a Ride to the Future
The ATS Group will support the Goddard Space Flight Center's science and technology community by facilitating frequent, affordable opportunities for access to space and shall be advocates of change to reduce the cost of access. The ATS Group will utilize it's experience and knowledge to provide comprehensive customer support throughout the entire mission cycle. This support will be thorough, innovative, and timely to ensure long term customer satisfaction.
Developing a Mission?
Looking for a Ride?
How far do you want to go today?


Netscape: Access to Space
Back
Forward
Reload
Home
Search
Guide
Images
Print
Security
Stop
http://accesstospace.gsfc.nasa.gov
Goddard Space Flight Center
Access To Space
Providing a Ride to the Future
The ATS Group will support the Goddard Space Flight Center's science and technology community by facilitating frequent, affordable opportunities for access to space and shall be advocates of change to reduce the cost of access. The ATS Group will utilize it's experience and knowledge to provide comprehensive customer support throughout the entire mission cycle. This support will be thorough, innovative, and timely to ensure long term customer satisfaction.
http://accesstospace.gsfc.nasa.gov
Looking for a Ride?
How far do you want to go today?

Distributed Knowledge Base




Data Admin Tools (Frame) - Microsoft Internet Explorer
File Edit View Go Favorites Help
Back Forward Stop Refresh Home Search Favorites History Channels Fullscreen Mail Print Edit
Address http://marketing1/ats2/FrameDataadmin.htm
Links
Access To Space
Data Admin Tool
Add A Mission
Launch Vehicles
Add New Vehicle
Add New Launch Site
Add Vehicle to Launch Site
Add Payload Performance Data
Missions
Add A Mission
Mission Name:
Mission Status: Manifested
Mission Budget: None
Mission URL Link:
Launch Date:
Launch Window Duration(min): 0
Launch Window Open/Close: TBD
Seasonal Window: TBD
Apogee(km): 0
Perigee(km): 0
Inclination(deg): 0
Arg Of Perigee(deg): 0
C3(km2/s2): 0
Ascending Node(deg): 0
or MLT:
Primary Payload Mass(kg): 0
Spacecraft Length(m): 0
Spacecraft Diameter(m): 0

The ATS Web Page Provides "Tool Boxes" for:

- *Access Opportunities*
- *Performance*
- *Interfaces*
- *Volume*
- *Environments*
- *"Wish List" Entry*
- *Educational Outreach*

New Page 1 - Microsoft Internet Explorer

File Edit View Go Favorites Help

Back Forward Stop Refresh Home Search Favorites History Channels Fullscreen Mail Print Edit

Address http://kerga/als2/alsxcb.dll/a?rform=sv_d%3D1%26sv_sub_d%3D1%26s%3D&mdm=sv_id%3D1%26sv_sub_id%3D0%26ar%3D&_html=&search=Search Links

Access To Space

General Information | Performance | Available Volumes | Interfaces | Environments | LaunchSites

Pegasus (PegasusXL)

Introduction

Accuracy

Mission Milestones

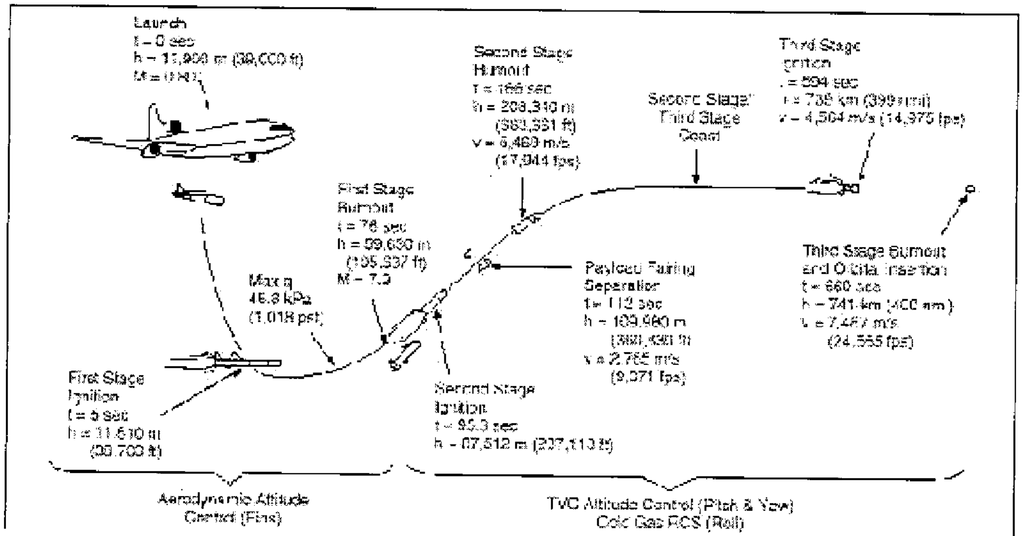
Propulsion Data

Ascent Profile

Ascent Timeline

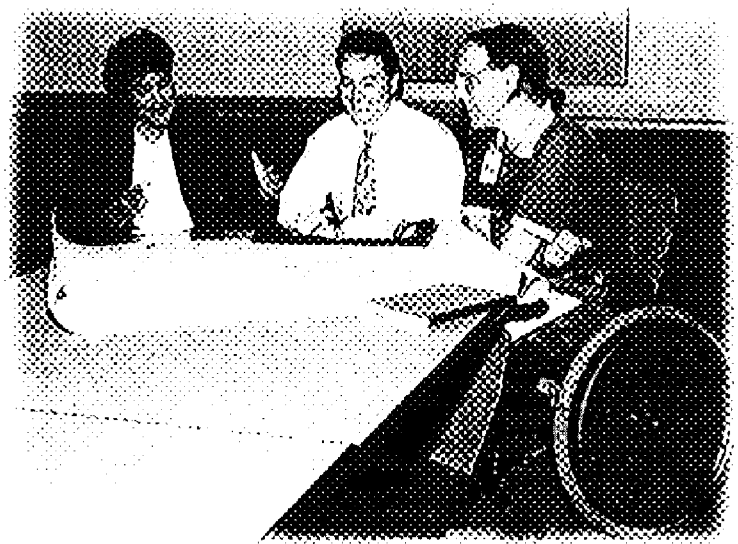
Payload Restrictions

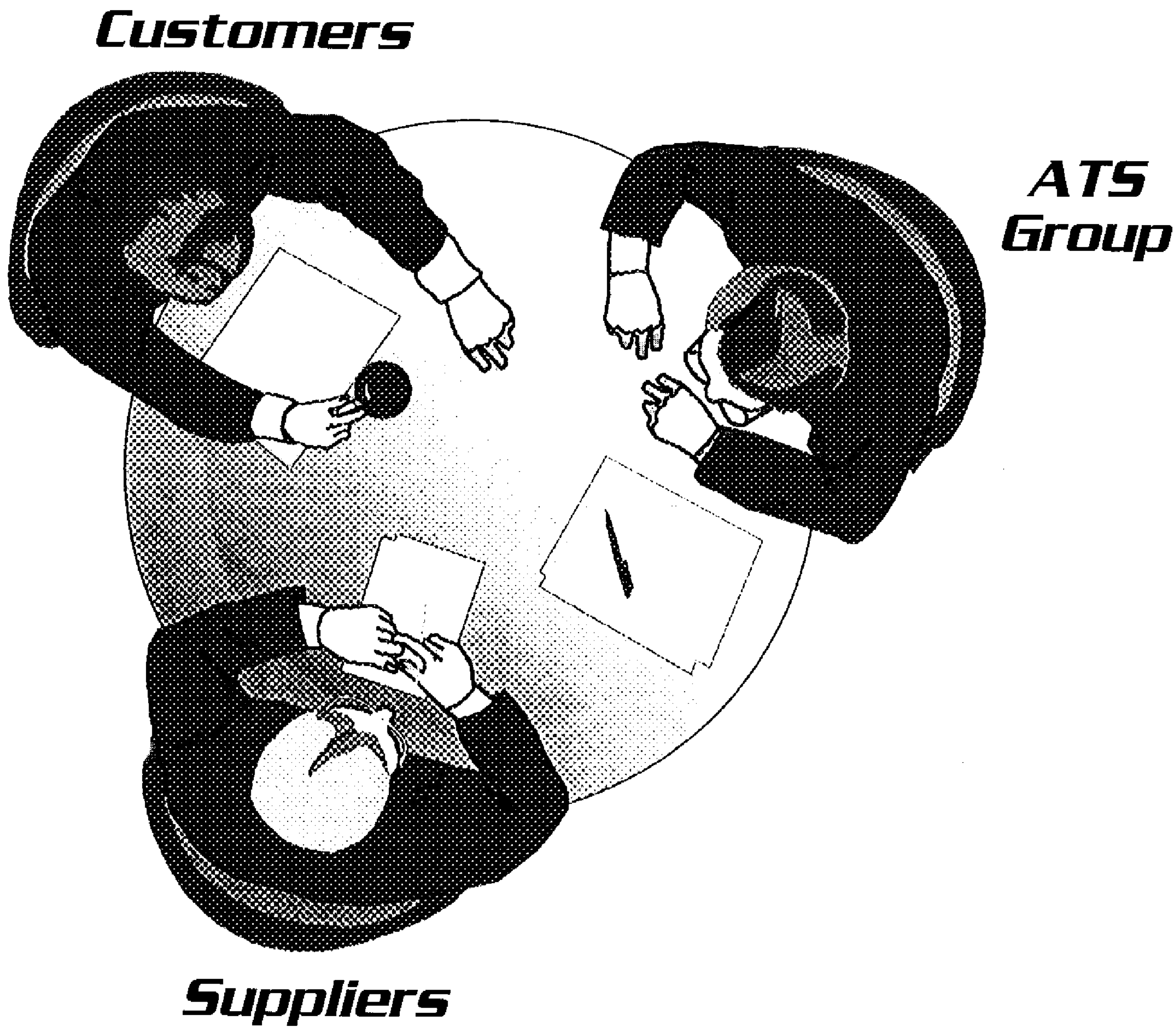
Ascent Profile

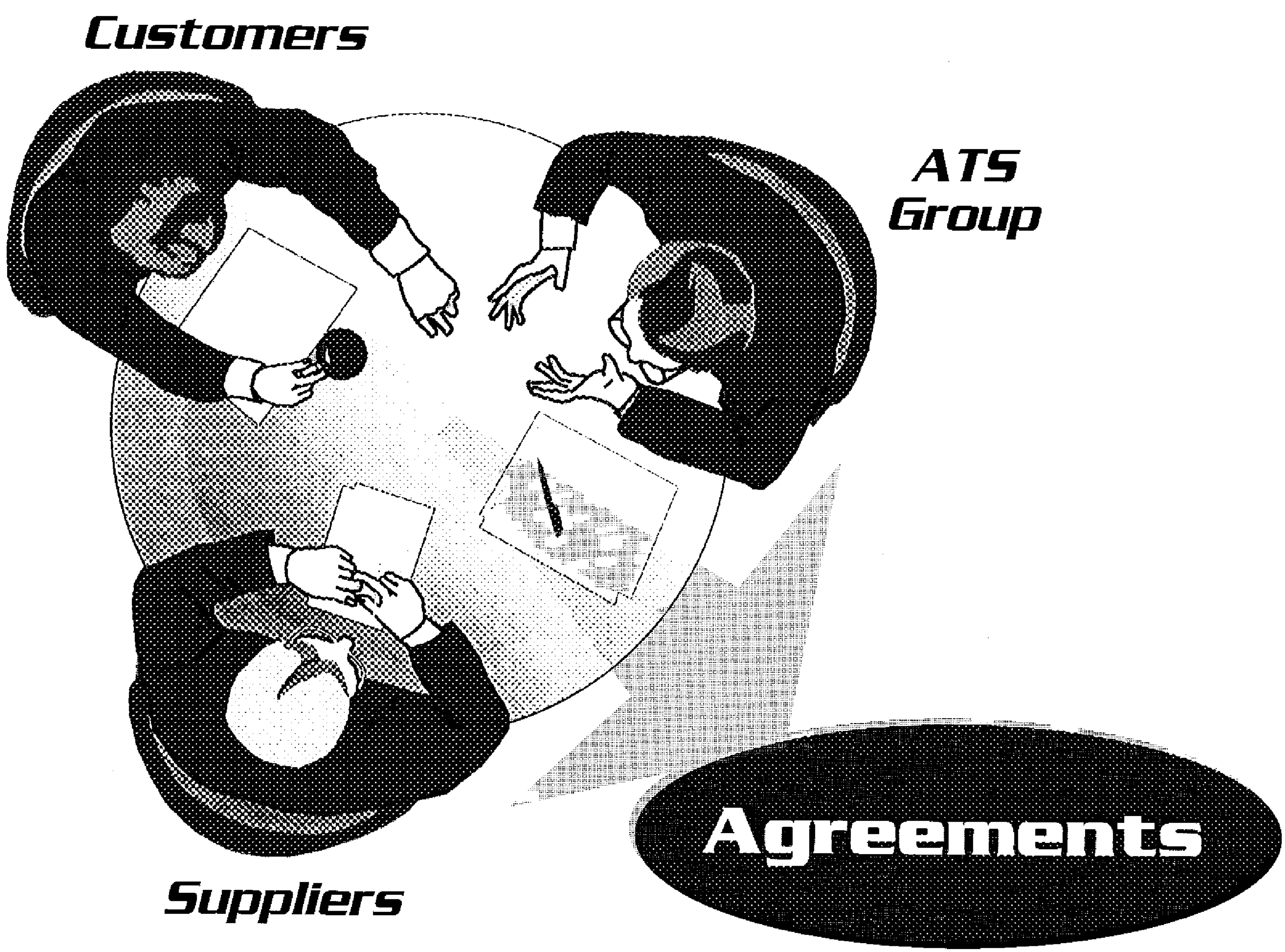


Local intranet zone

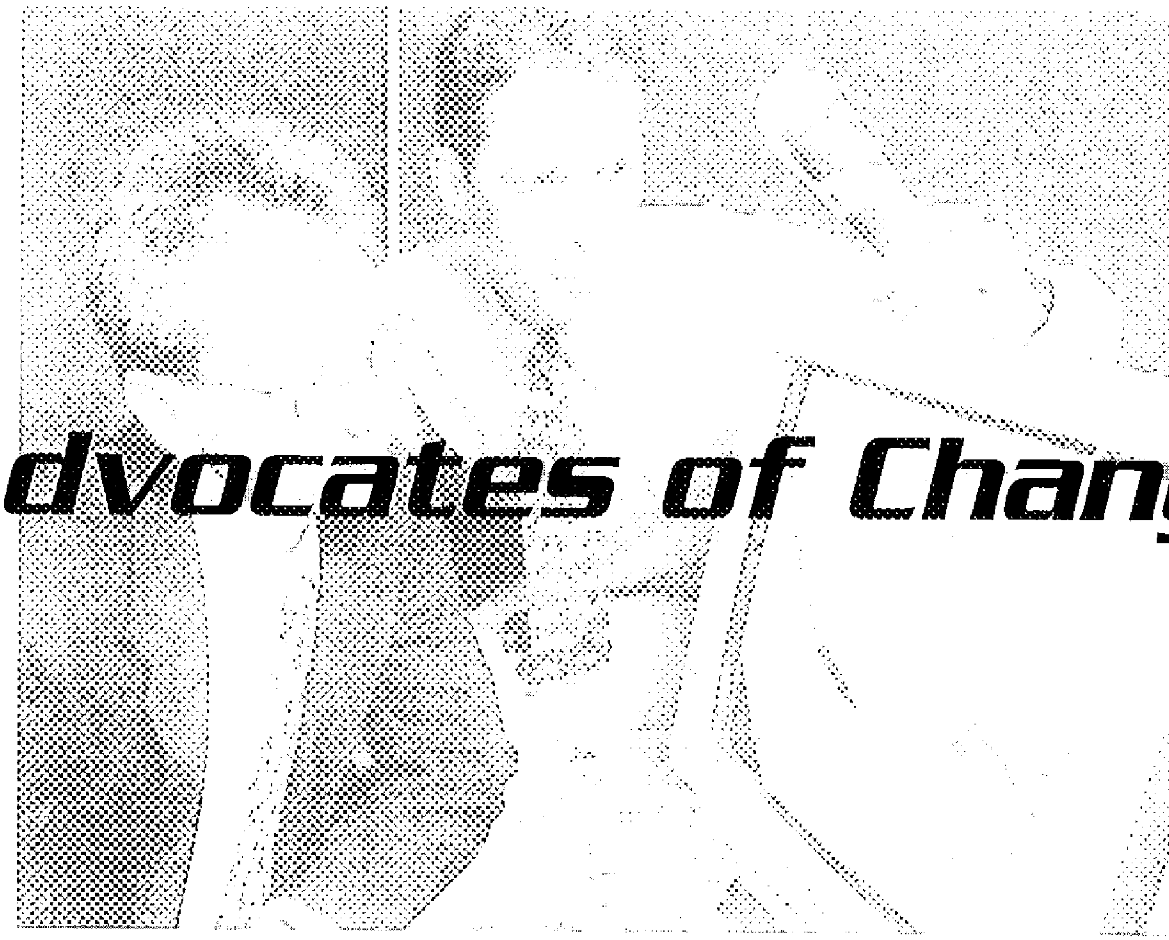
Customer Satisfaction

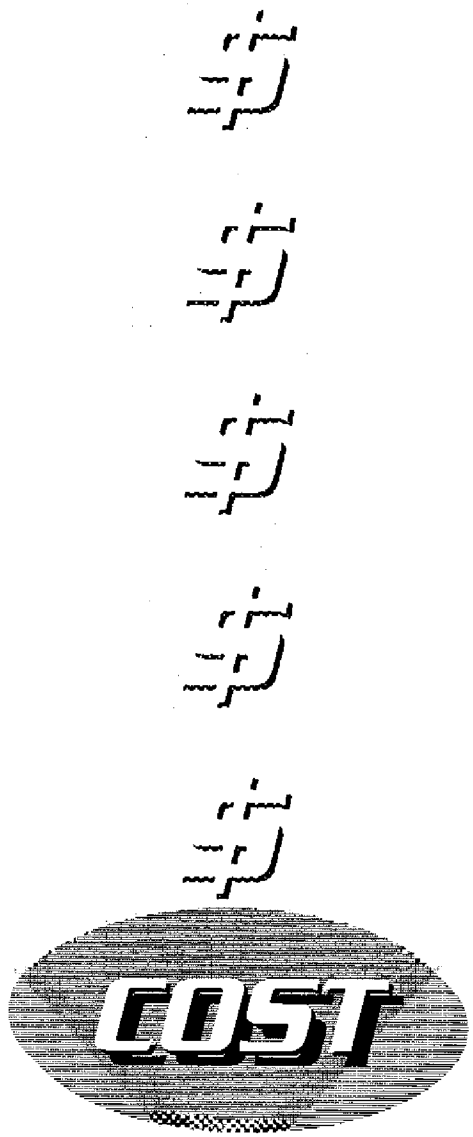


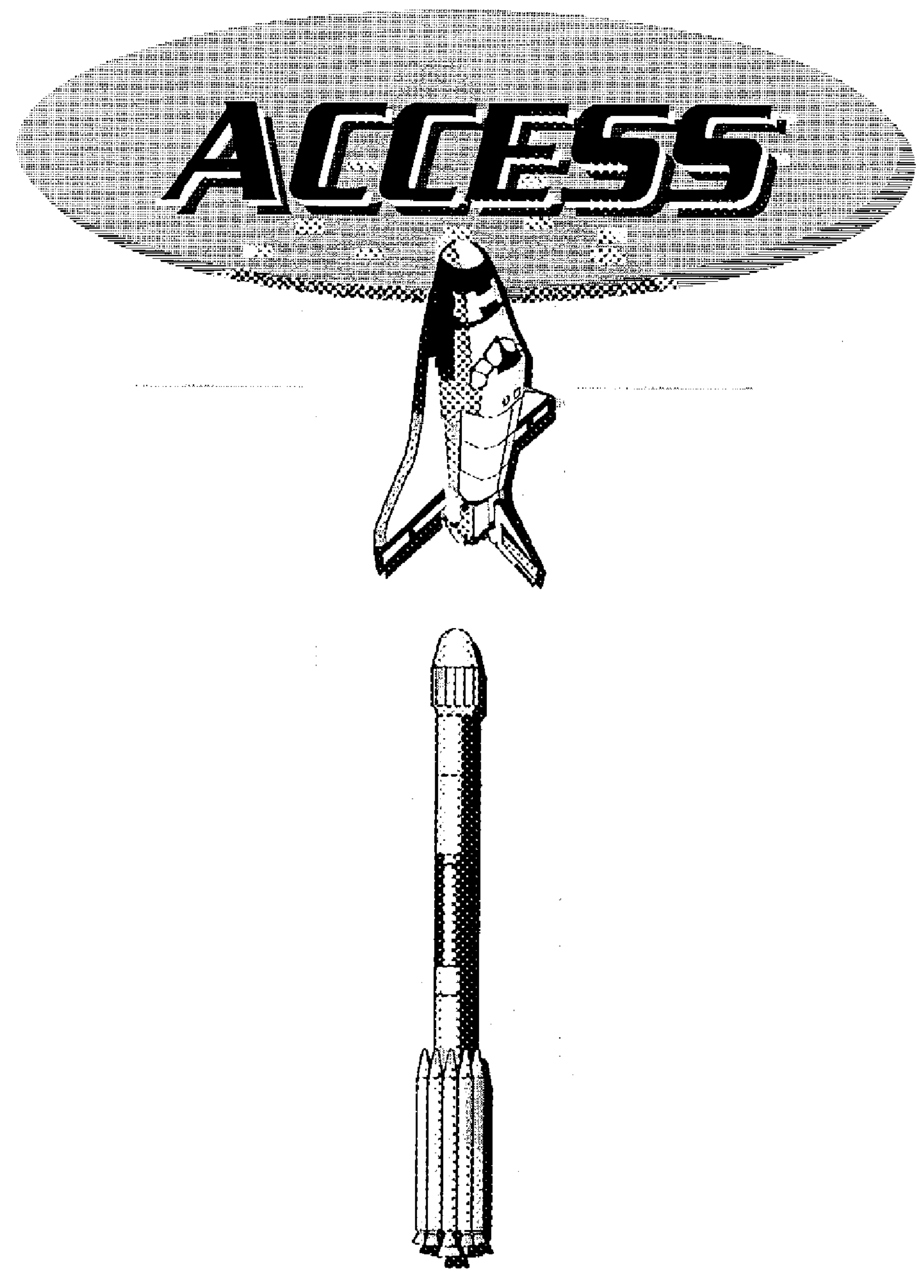

Customers
ATS
Group
Suppliers


Customers
ATS
Group
Suppliers
Agreements

Advocates of Change




$
$
$
$
$
COST


ACCESS

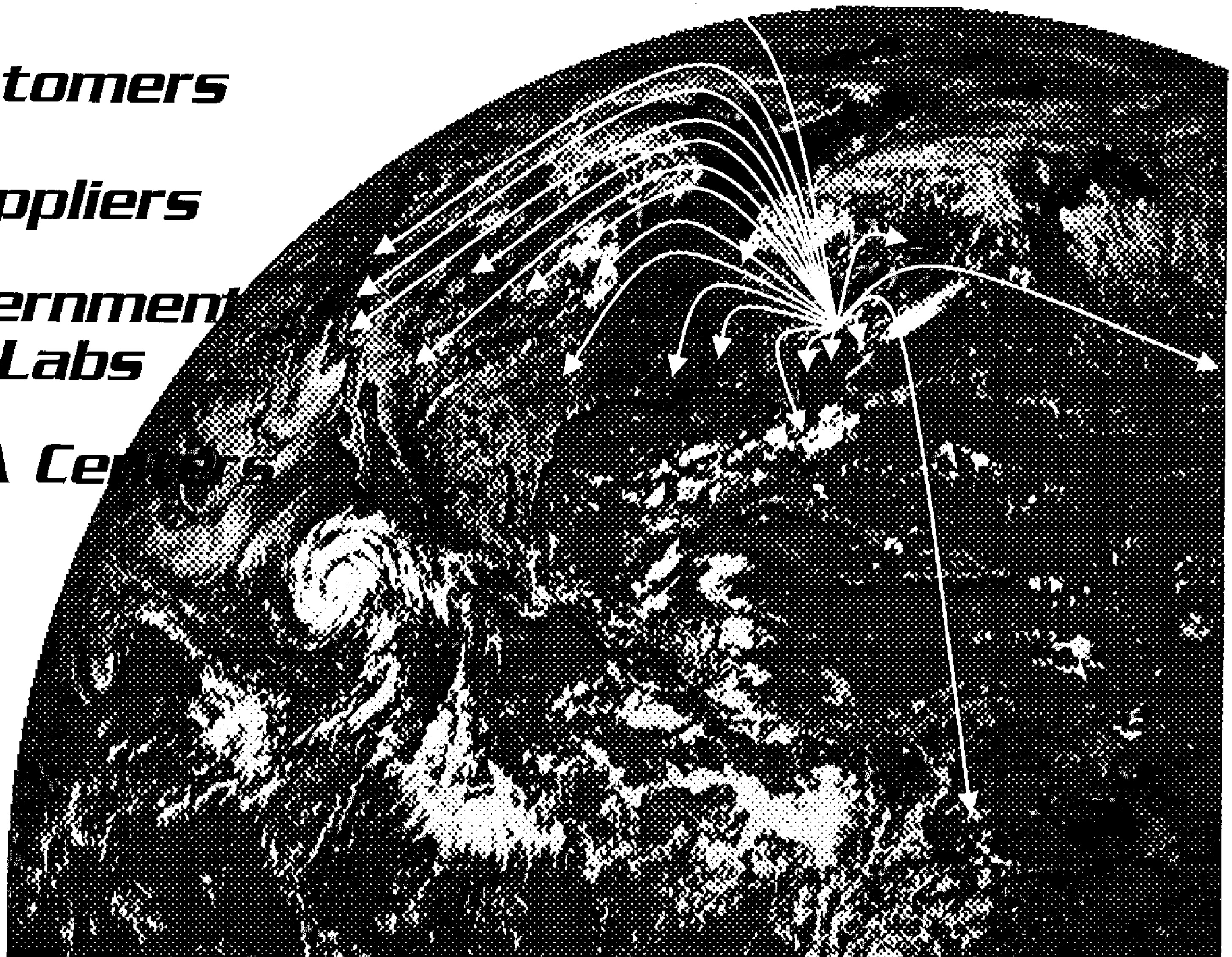
Partnerships

Customers

Suppliers

Government Labs

NASA Centers



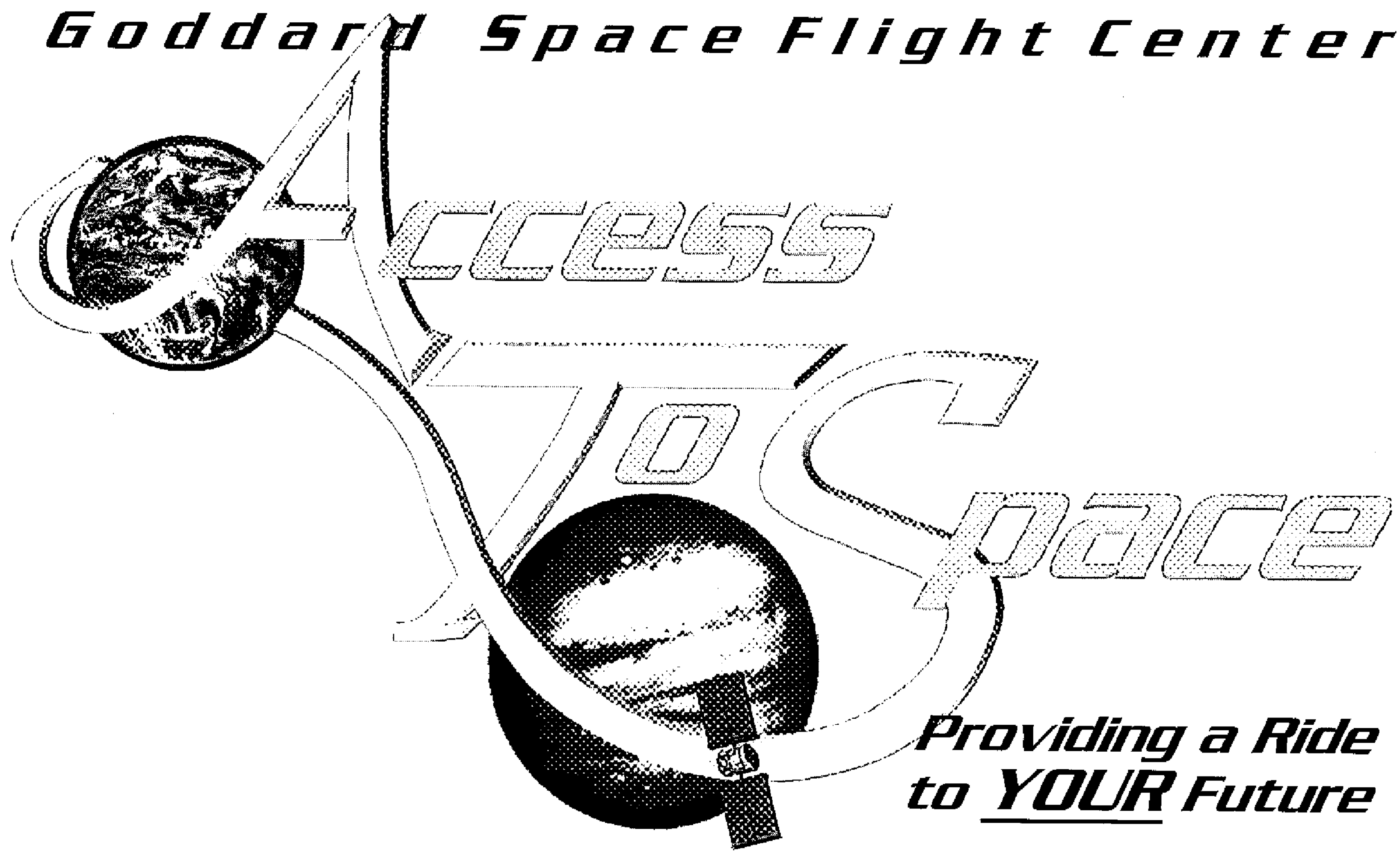
For Further Information, Please Contact:

- ATS Group Leader
  - Bill Cutlip

    William.E.Cutlip.1@gsfc.nasa.gov
    Voice: (301) 286-0438
    FAX: (301) 286-~~1696~~ 0232

- Project Formulation Office
  - Tom Taylor

    Thomas.S.Taylor.1@gsfc.nasa.gov
    Voice: (301) 286-8388
    FAX: (301) 286-0232


Goddard Space Flight Center
Access To Space
Providing a Ride
to YOUR Future

Goddard Space Flight Center

Access To Space — Providing a Ride to the Future

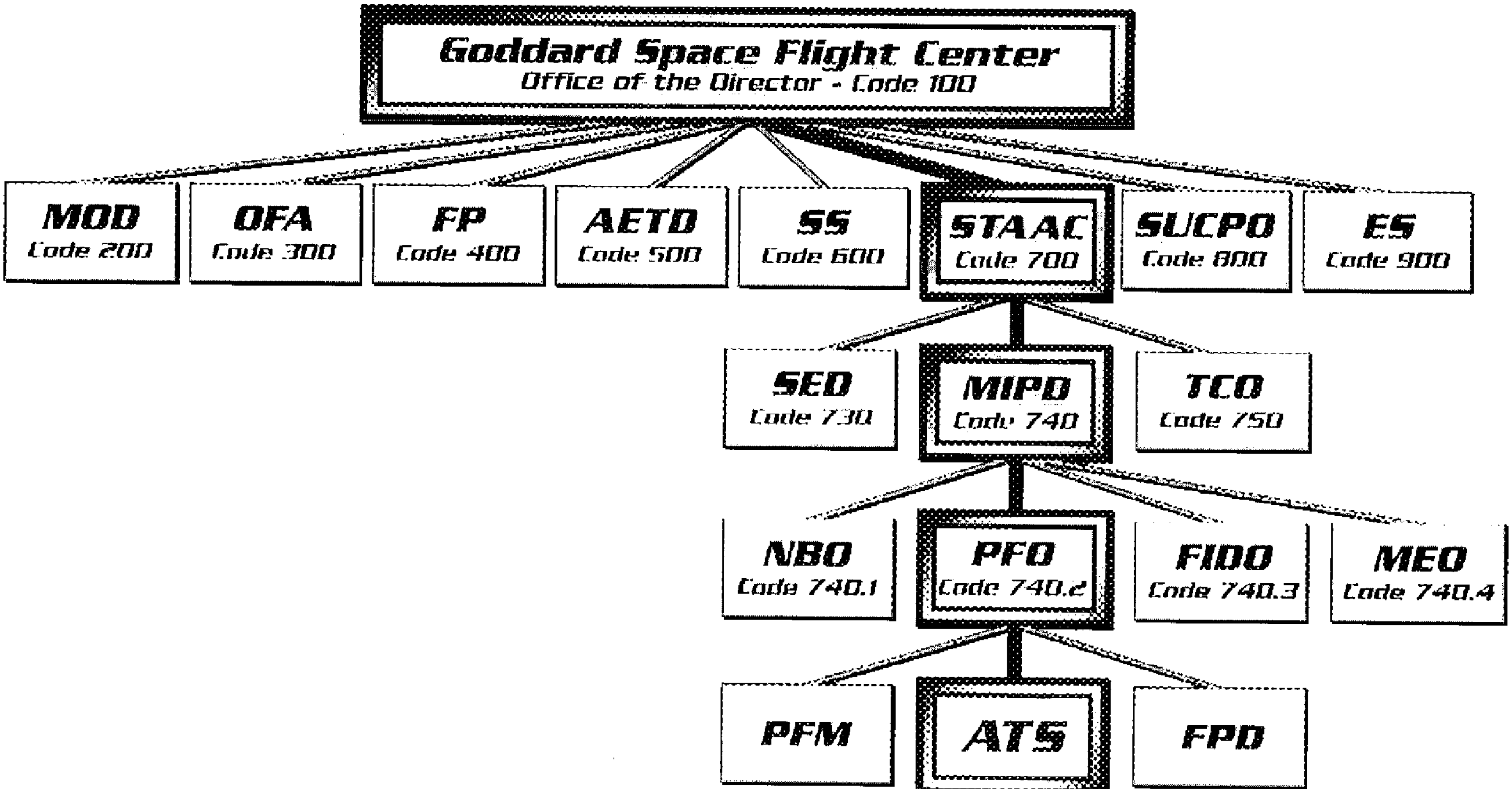
Access To Space Group

— ATS/NRO Rideshare Conference —

William E. Cutlip
Group Leader, Access To Space Group

GODDARD SPACE FLIGHT CENTER

Where's ATS?


Goddard Space Flight Center
Office of the Director - Code 100
MOD
Code 200
OFA
Code 300
FP
Code 400
AETD
Code 500
SS
Code 600
STAAC
Code 700
SUCPO
Code 800
ES
Code 900
SED
Code 730
MIPD
Code 740
TCO
Code 750
NBO
Code 740.1
PFO
Code 740.2
FIDO
Code 740.3
MEO
Code 740.4
PFM
ATS
FPD

Here's ATS

Thomas Taylor, Chief

Sandra Cauffman, Deputy Chief
Patrice Cogswell, Secretary

Project Formulation Managers (PFM)

- Caruso, Paul, Sr. PFM
- Durning, John
- Galloway, John
- Gervin, Jan
- Grady, Jean
- Jenstrom, Del
- Pacini, Linda
- Park, Elizabeth
- Seery, Bernie

Access to Space Agents (ATSA)

- Cutlip, Bill, ATS Group Lead
- Buchanan, Robert
- Goeser, Francis M.
- Leon, John
- Vacant
- Vacant
- Woodall, Clyde

Carrier Managers (HST)

- Hubbard, Mark
- Krupacs, Eric

Business Management Office (FPD)

- Sasce, Dino
  Resource Analyst
- Vacant
  Resource Analyst
- Marechek, Laura
  Business Support Specialist

Technical Support

- Azzolini, John
  Advanced Project Technologist (SED)
- Badri Younce
  Spectrum Manager (FPD)

Mission Statement

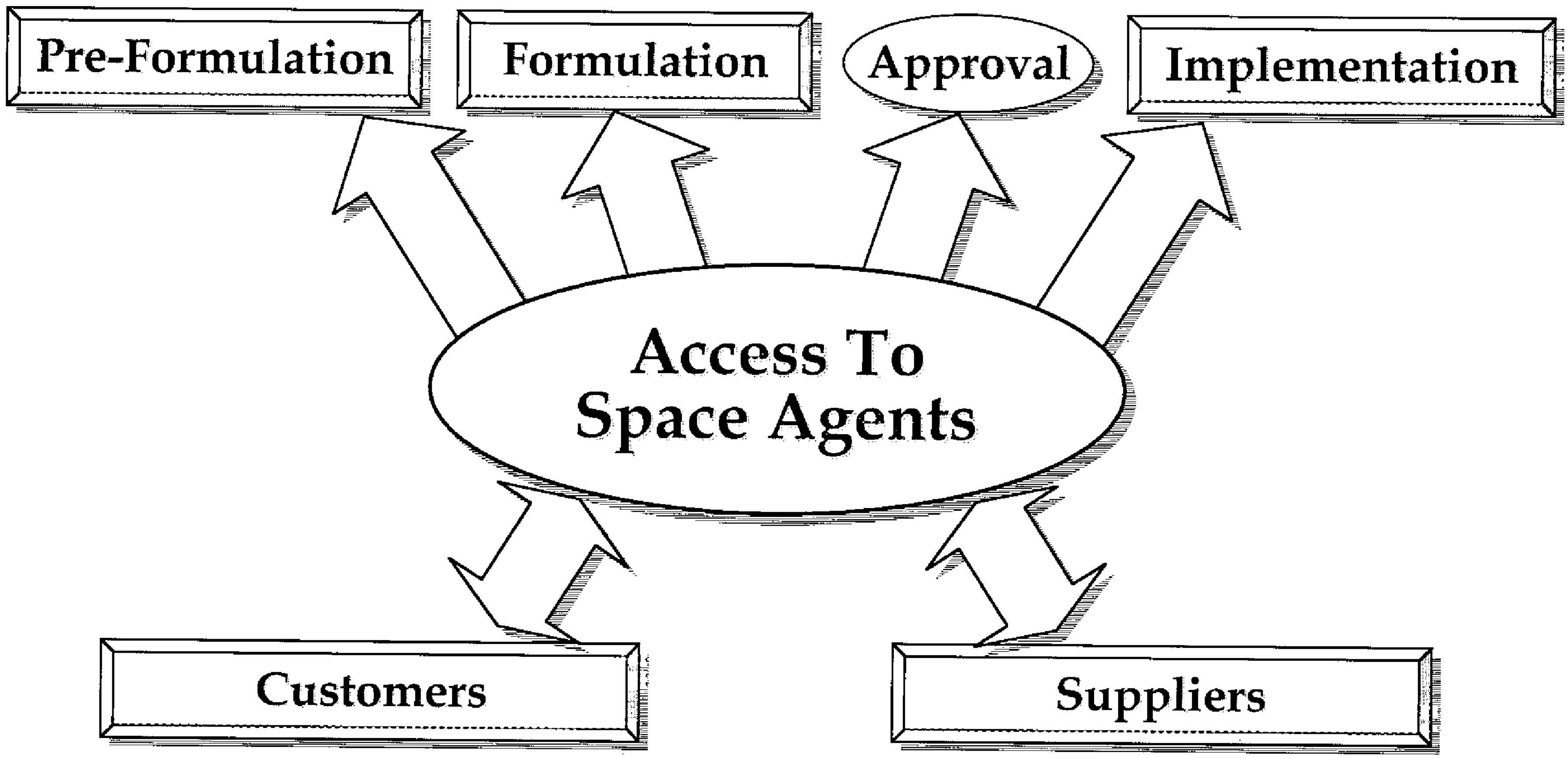
"The ATS Group will support the Goddard Space Flight Center's science and technology community by facilitating frequent, affordable opportunities for access to space and shall be advocates of change to reduce the cost of access. The ATS Group will utilize its experience and knowledge to provide comprehensive customer support throughout the entire mission cycle. This support will be thorough, innovative, and timely to ensure long term customer satisfaction."

(ATS Strategic Plan Signed By GSFC Center Director 10/22/98)

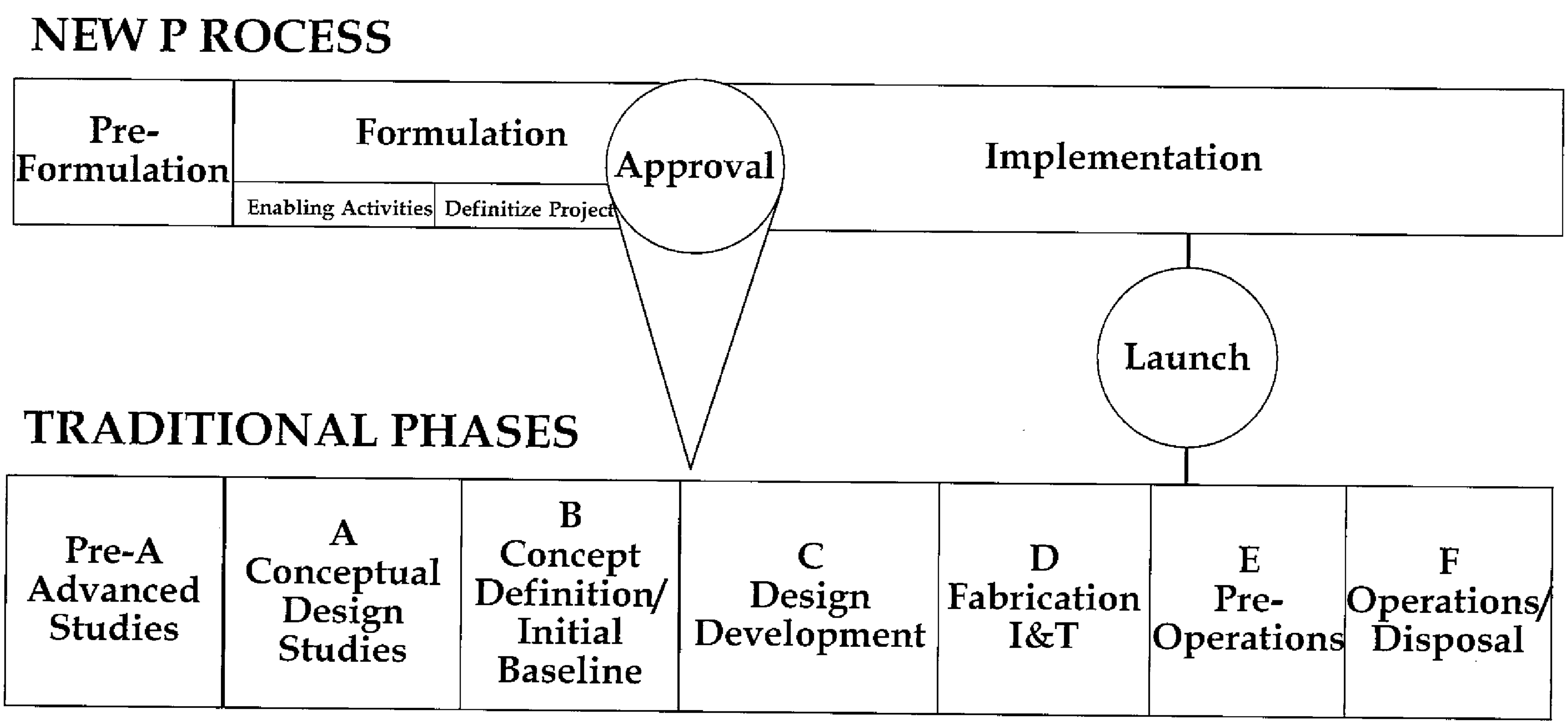
Charter

- Provide frequent, affordable opportunities for GSFC customers to make new measurements across a wide range of instrument platforms
- Maintain models/database of world-wide ATS performance/interface capabilities, access to space opportunities, and customers' needs
- Facilitate the reduction of ATS cost over the full mission life cycle
- Participate in entire mission life cycle

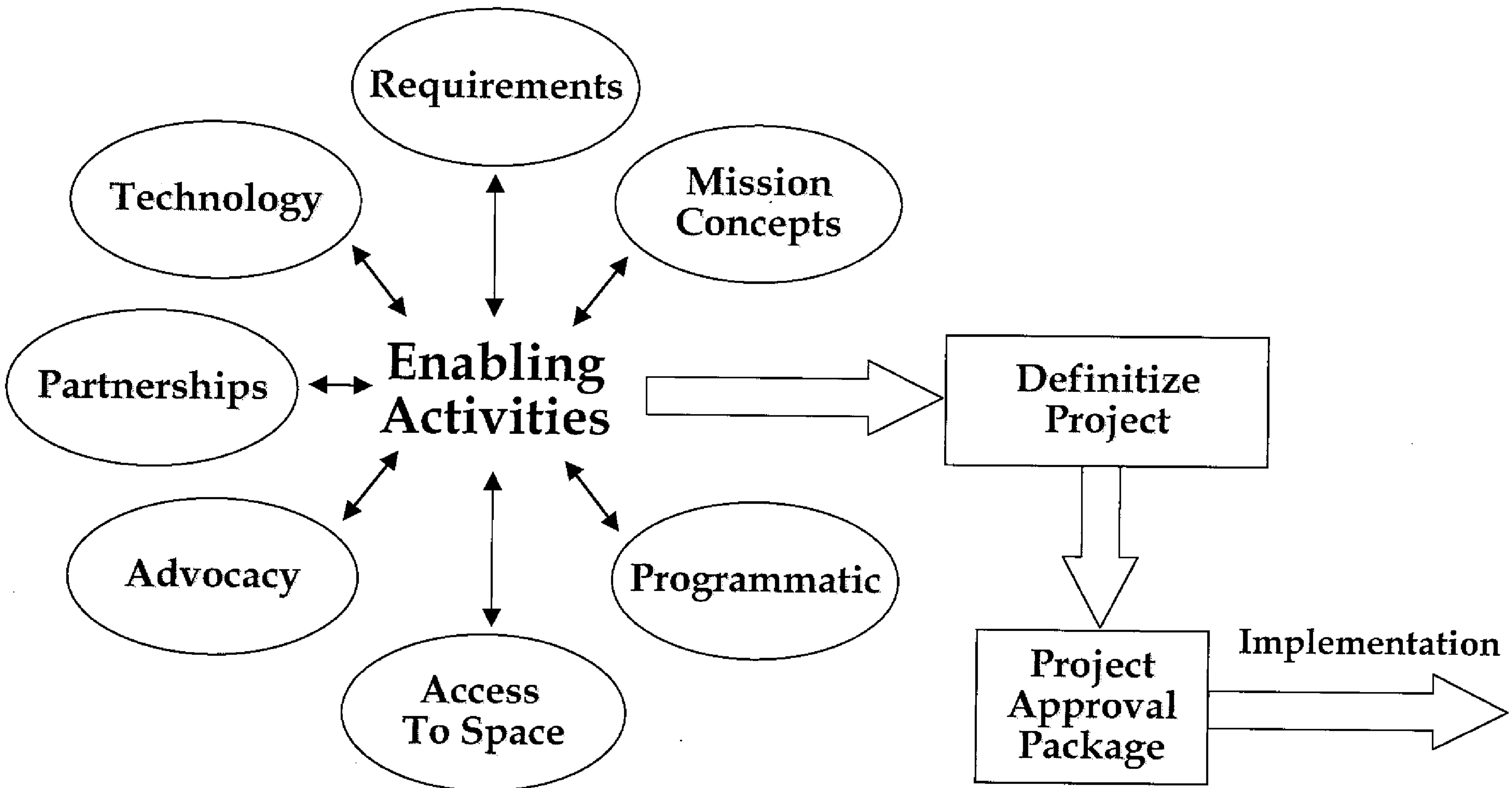
Process Flow



Old Versus The New



Project Formulation



Project Support

- Pre-Formulation/Formulation Process
  - "The Access To Space Agent (ATSA) supports all Access To Space-related technical and programmatic processes in support of GSFC's development of feasible mission concepts, Project Formulation and Implementation activities."
  - The ATSA is responsible for the following :
    - Provision of timely, comprehensive information regarding access opportunities, technical details specific to each opportunity, related cost information, and customer satisfaction with the products delivered.
    - Development of Web-based tools and databases to support assessment of all access modes and related technical and programmatic aspects.
    - Formulation and implementation of a standardized assessment package.
    - Formulation and implementation of MOAs with other Centers to facilitate.

Web-based Tools and Database: Mission Statement

"Develop and maintain a web site that provides both the information and the tools to assist mission planners in selecting and planning their ride to space. This includes the evaluation of single payloads vs. ride-sharing to reduce the cost of access to space."

Web Site Contents

- Database of information on foreign and domestic launch vehicles
  - The equivalent of an abbreviated on-line user's guides in a single location with the ability to view side-by-side comparisons of data in like formats
- Database of all missions planning to fly
  - Future concepts, Proposed missions, Manifested
- Interactive tools to quickly and easily scan through the data to search for candidate vehicles and ride-sharing/co-manifest opportunities
- Ability for registered users to add missions and share ideas to foster partnerships

Implementation Plan

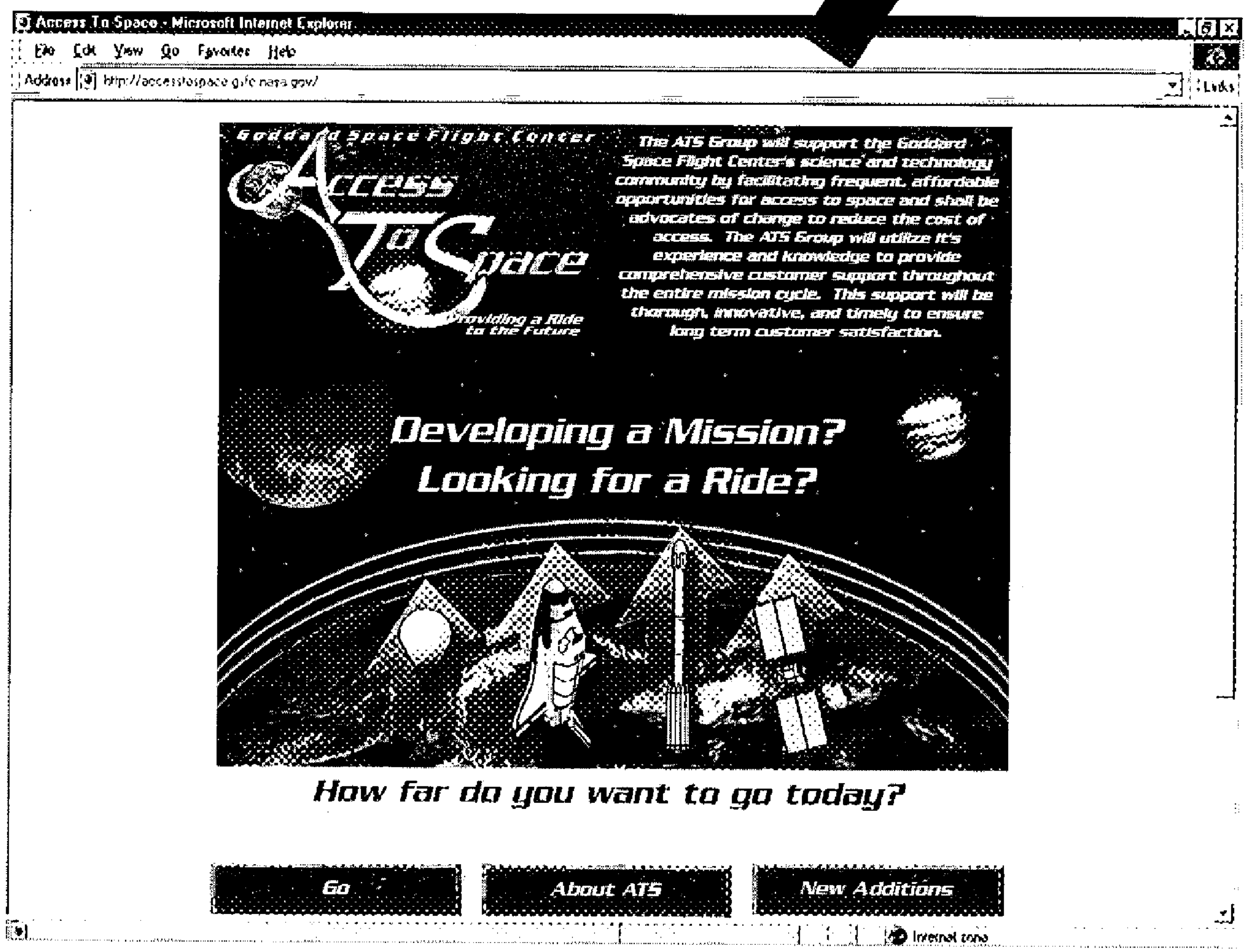
- Design and develop the core system
- Populate the databases with current information
- Place Release 1 online and publicize the site
- Receive customer feedback and enhancement suggestions
- Continue to expand functionality of the site
- Work with other organizations, both commercial and government, to continually evolve to meet all user's needs

Where We Are

- *Design and develop the core system*
  - Initial release is in testing phase
- *Populate the databases with current information*
  - LVs: Have been working with industry suppliers since last Fall to supply data in a standard/consistent format
  - Missions: Already contains mission information from NASA's database and other mission information from NRO
- *Place Release 1 online and publicize the site*
- Release 1 will go online in May
- We are demonstrating the site at this conference
  - Receive customer feedback and enhancement suggestions

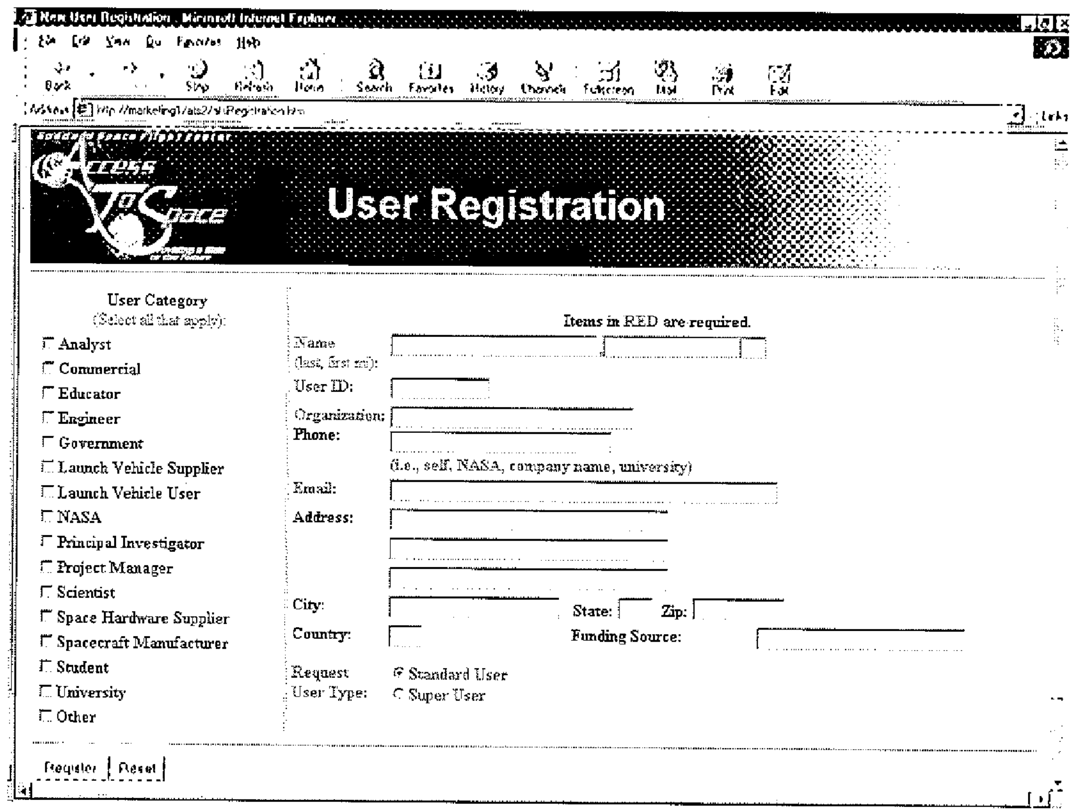
ATS Home Page

http://accesstospace.gsfc.nasa.gov



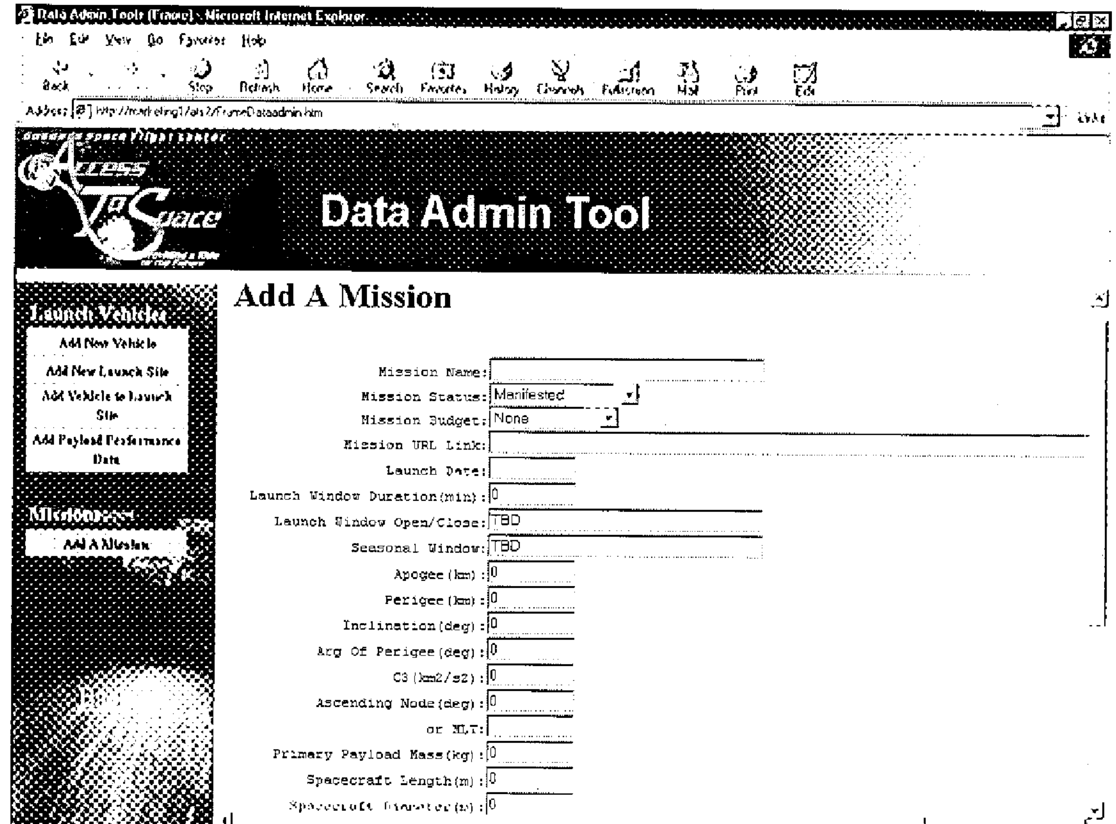
User Registration

- All users can browse the site by entering as a 'guest'
- Registered users gain additional benefits such as:
  - Stored user sessions
  - Printable "walk-away packets"
  - Access tools to enter/edit mission data into the mission database



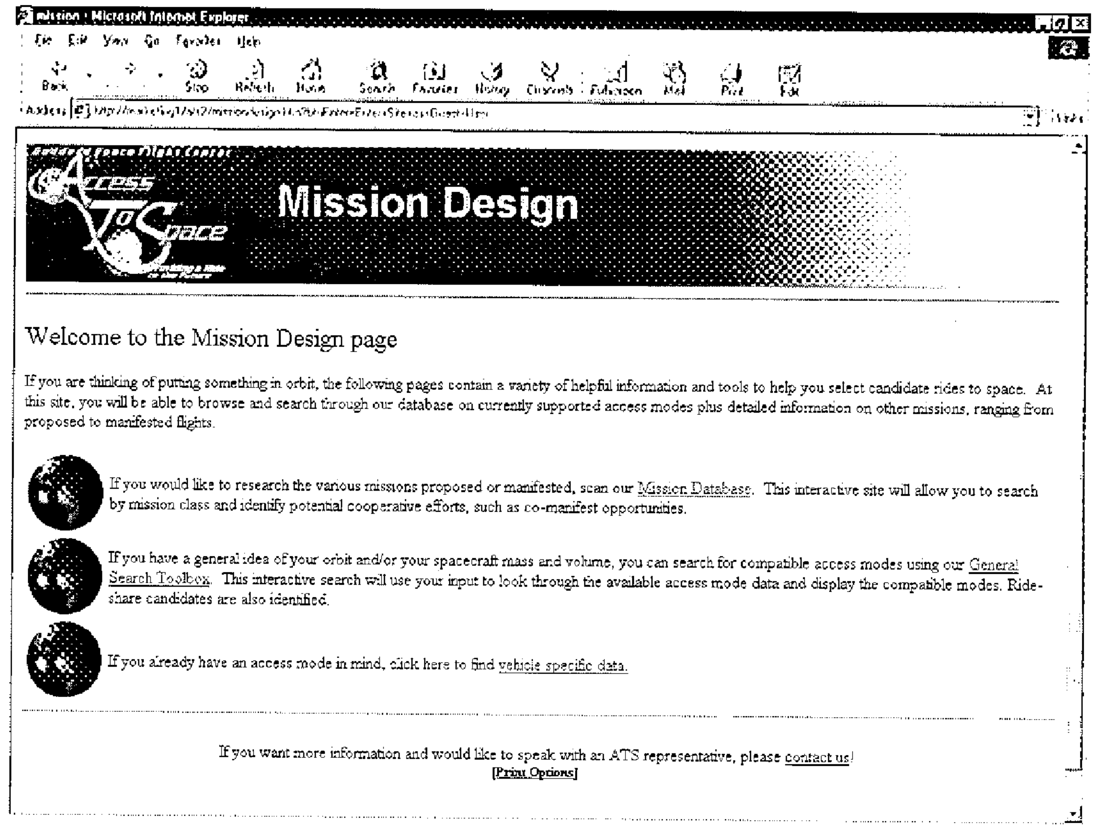
Mission Data Input

- Registered users enter mission data through a series of data input panels
- Data topics include:
  - Orbit Parameters
  - Secondary/Co-manifest
  - Spacecraft Characteristics
  - Launch Vehicle
  - Other Mission Notes
  - Contact Information



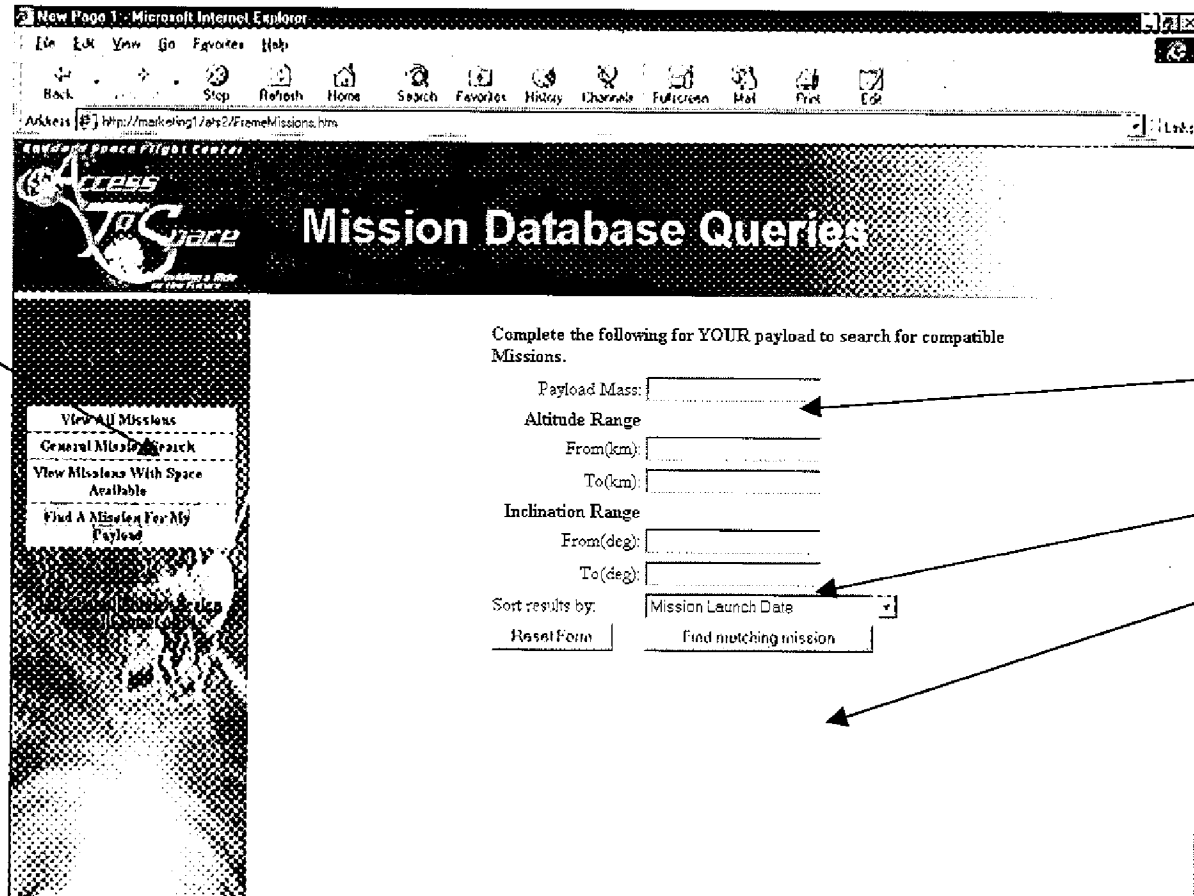
Mission Design Home Page

- When using the mission design site, the user has three options from the main page:
  1 - Query Mission Database
  2 - Search for candidate rides
  3 - Investigate Launch Vehicles in detail



Option 1: Query Mission Database

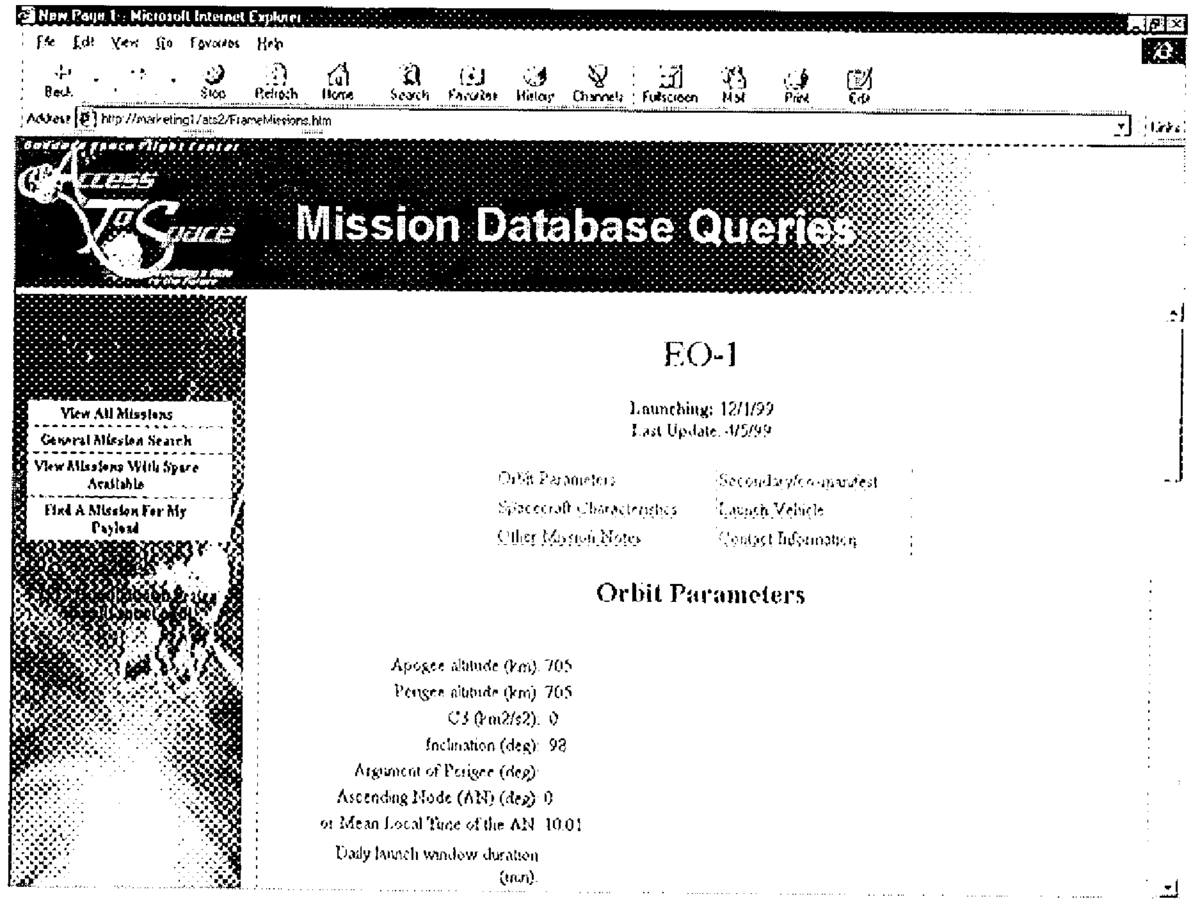
Sort options



- Input search data
- Click "go"
- Results returned here

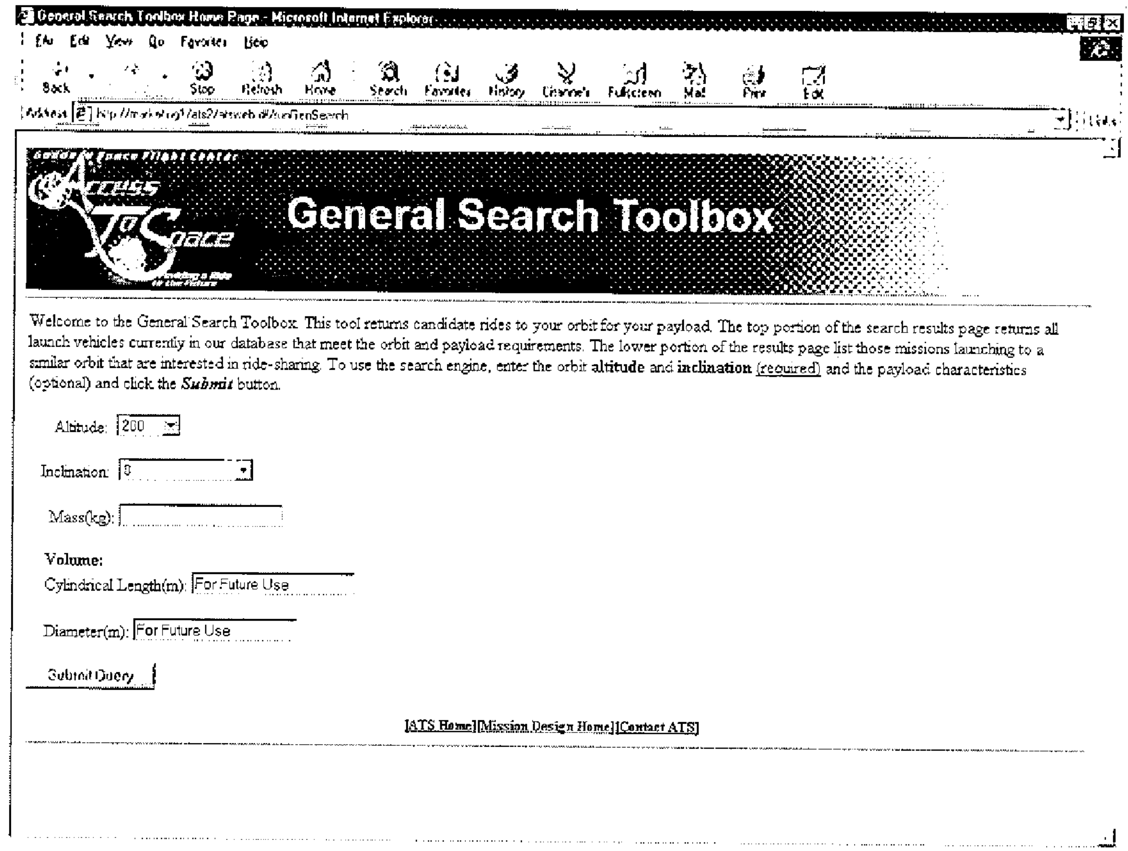
From the sort results, you can view the mission details

- Orbit Parameters
- Secondary/Co-manifest
- Spacecraft Characteristics
- Launch Vehicle
- Other Mission Notes
- Contact Information



Option 2: General Search Toolbox

- Enter target orbit and payload mass
- Query returns candidate launch vehicles and potential ride-share matches



Candidate Launch Vehicles and Ride-Shares

- Launch Vehicles
  - Based on the payload mass and orbit requested, the vehicle performance curves are scanned and the vehicle returned if the orbit can be achieved
  - The user can then click on the selections to research the candidate vehicles in detail
- Ride-Shares
  - Additionally, the mission database is scanned to identify ride-share candidates based on the payload mass and orbit proximity
  - The results are separated by mission status
  - You may click on the mission name to view the mission details

Results Page

General Search Toolbox Results

Search results for Altitude of 450(km), Inclination of sun-synchronous(deg).

Access Mode	*Max Payload (kg)*
Delta II(7920-9.5)	3560
Delta II(7920-10)	3426
Pegasus(PegasusXL)	277

Select Results for Shared Ride Opportunities
Select a mission name for detailed information

Manifested

Mission Name	Launch Date	Secondary Status	Payload Mass (kg)	Allocated Mass (kg)	Allocated Volume (Cylindrical) dia.(m) x length(m)	Secondary Application Deadline
Orbview-4	07/01/2000	Secondary/co-manifest opportunity available	300	300	1.1 x 1.53	07/01/1999
LV-013	03/01/2000	Secondary/co-manifest opportunity available	0	150	0.66 x 0	07/01/1999

Proposed Missions

Mission Name	Launch Date	Secondary Status	Payload Mass (kg)	Allocated Mass (kg)	Allocated Volume (Cylindrical) dia.(m) x length(m)	Secondary Application Deadline
SAFIRE S		Looking for a ride	200	0		

Future Concepts

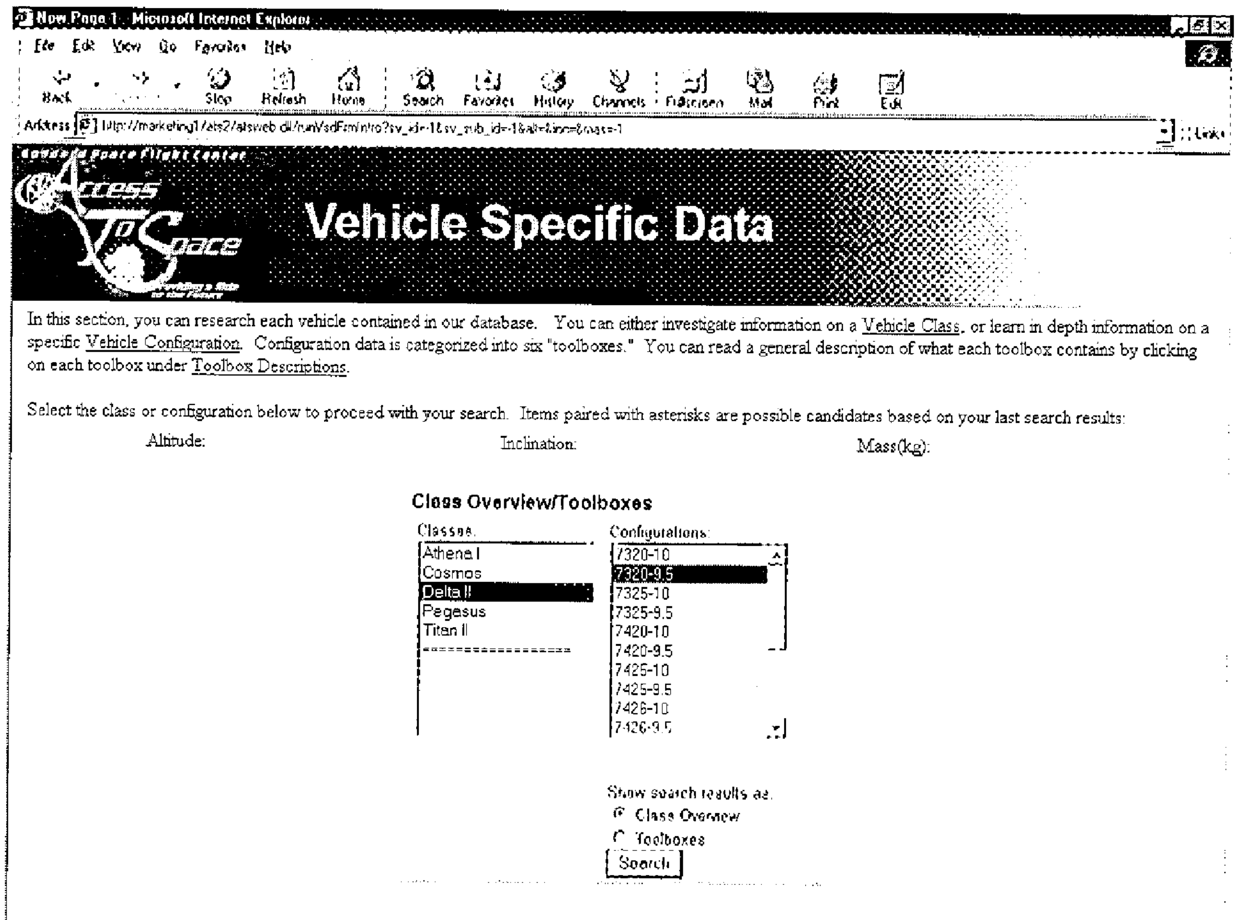
					Allocated Volume	Secondary

Option 3: Launch Vehicle Toolboxes

- The launch vehicle toolboxes provide the user with a wealth of data on each vehicle in areas such as:
  - General Information/Overview
  - Performance
  - Available Volume
  - Environments
  - Payload Interface
  - Launch Sites

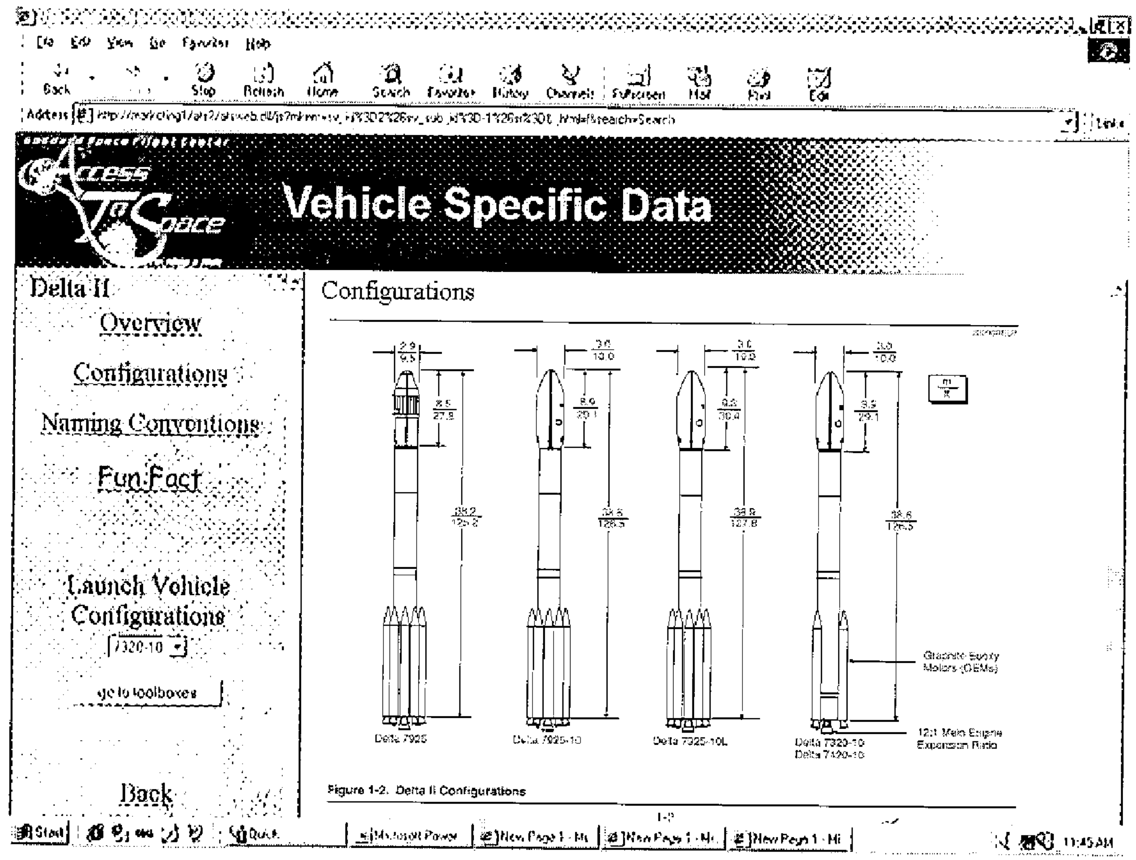
Option 3: Launch Vehicle Toolboxes (Continued)

- On the first page, you select the class and/or configuration you wish to research



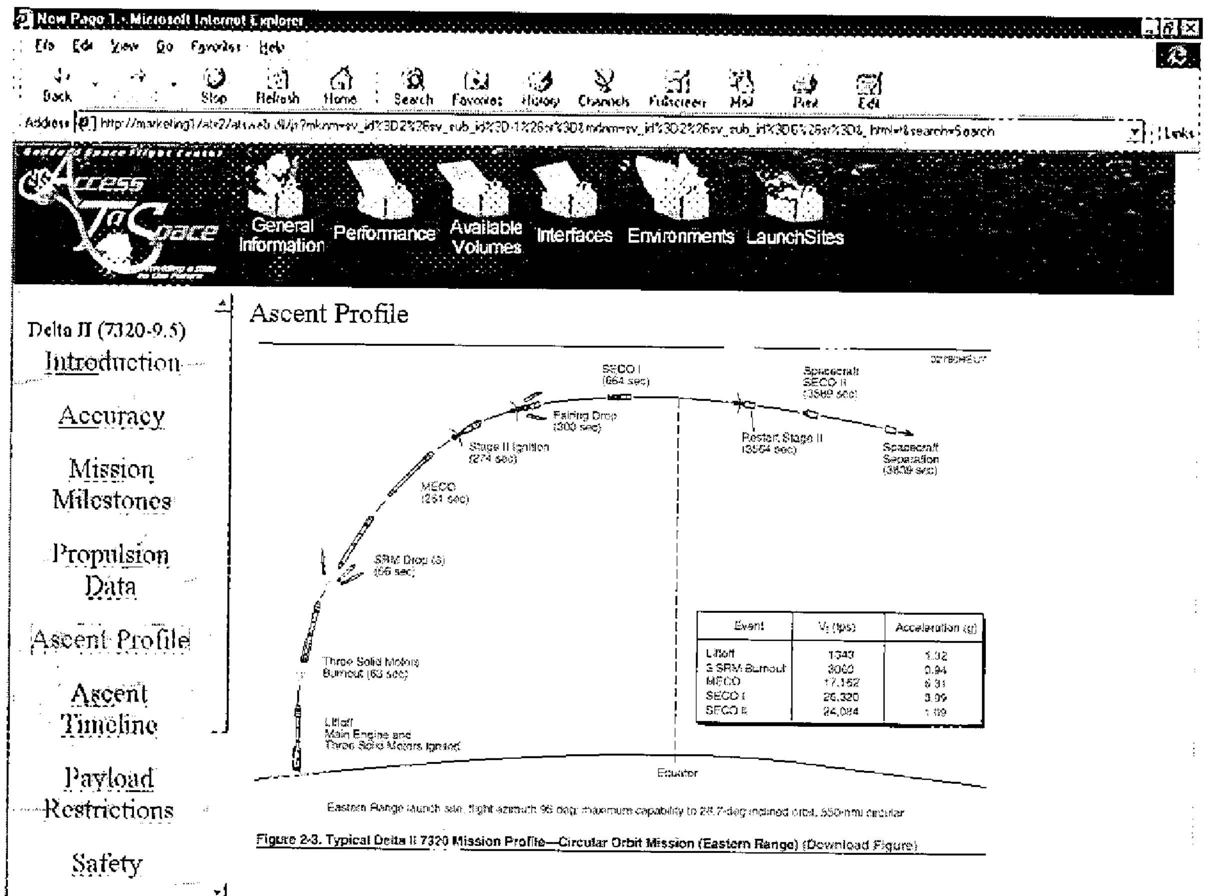
Vehicle Class Overview

- For vehicle class information, click on the menu selections on the left menu
  - Vehicle History and Description
  - Configurations Available
  - Naming Conventions
  - Educational Outreach



Vehicle Configuration Details

- To view configuration information, use both the top and side menus
- The top menu allows you to select the toolbox (major category)
- The side menu presents the topics contained in each toolbox



Walk-Away Packet

Once you have completed your session, you may go to the "Print Options" selection tool. This tool allows you to select items from the toolboxes and searches that you want to print, alleviating the need to print individual pages.

Access To Space Interactive Web Site

Vehicle Data Packet for user
Dr. Robert H. Goddard, XII
Launch Vehicle Information for the
Pegasus XL

January 20, 1999

What We Have Accomplished

- We have developed one single location for mission planners to seamlessly investigate the three means to reach space:
  - Ride share
  - Co-manifest
  - Single payload

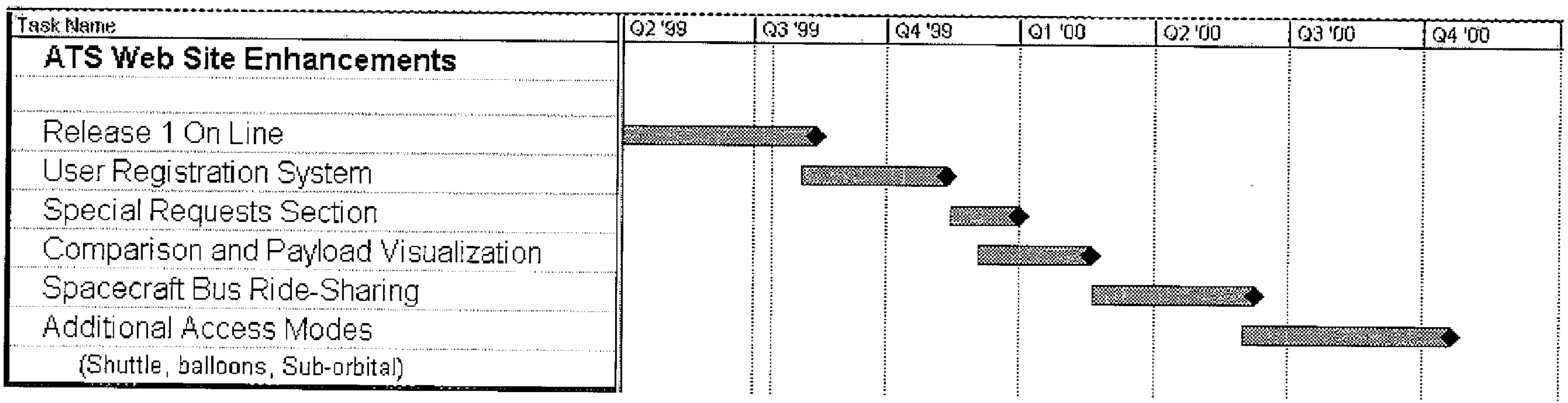
What We Need

- Full involvement from the Access Mode Supplier community
  - The basic tools are in place, but we need the vehicle data to make the site a true "portal" to the access to space world
- Full involvement from everyone who has a ride or is looking for a ride

Planned Enhancements

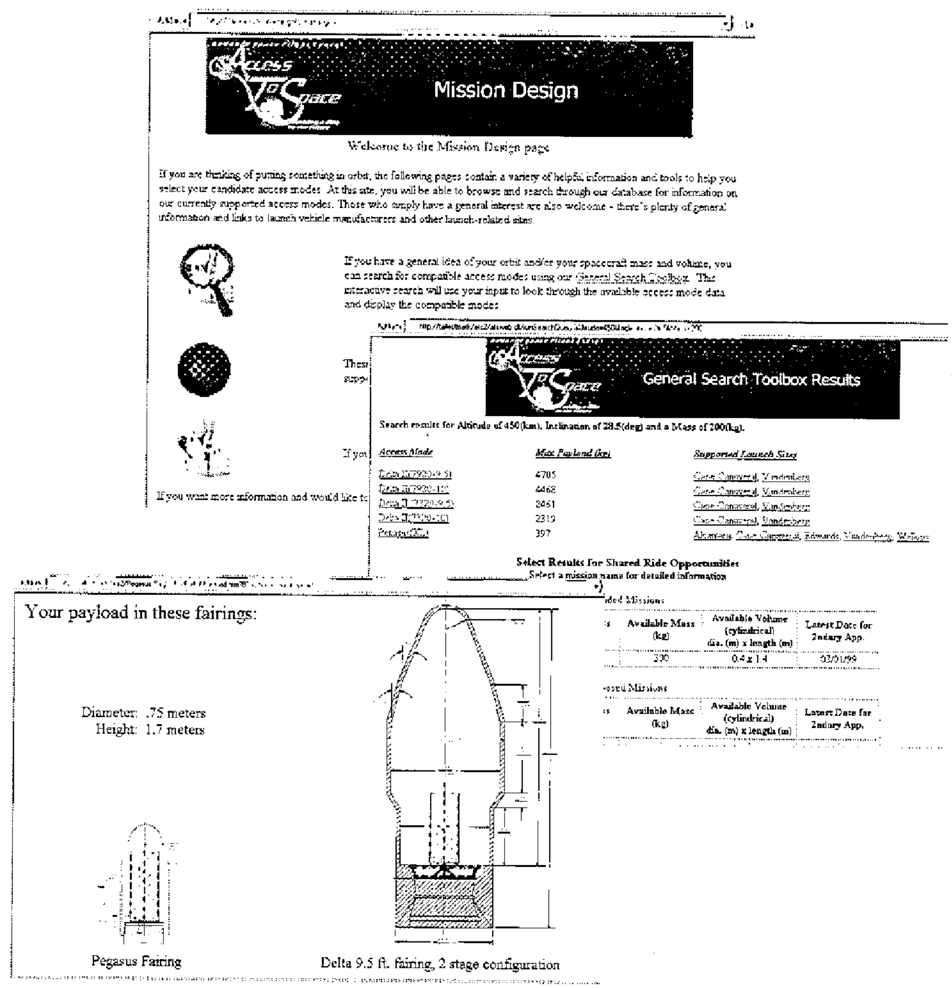
- Add a user-registration system
  - Stored user sessions
  - Printable 'walk-away' packets
  - User-tools to add missions to the database
- Comparison and payload visualization
- Special requests section
- Expand ride-sharing for spacecraft bus availability
- Expand to other access modes (Shuttle, balloons, sub-orbital)

Milestone Schedule



Formulation Assessments
(Web Assisted)

- Address All Access Modes
  - ELVs, RLVs, Balloons, Shuttle, Spacecraft, Shared Rides
  - U.S. and Foreign, Government and Commercial
- Phase I/II Process
  - Phase I identifies
    - Project Specifics
    - Potential Access Modes
      - ✓ Technical & Programmatic specifics for each
    - First Cut Trade Space
  - Phase II fine tunes, based on Customer input on Phase I



Potential Access Modes
(Summary Sheet Example)

- Shuttle
  - Inclination and "Shuttle-compatible" mods are show-stoppers
    - Time for plane change excessive
- High Altitude Balloons
  - Altitude and time-on-orbit requirements are show-stoppers
- Instrument Only Ride
  - Potential Access Mode
- Expendable/Reusable Launch Vehicles
  - Potential Access Mode

Potential Launch Vehicles
(Summary Sheet Example – all prices are estimates from public sources)

- Expendable Launch Vehicles

– Atlas IIA	SLC-3 at VAFB	Massive Performance Margin	$85M
– Titan II SLV	SLC-4W at VAFB	Elliptical Orbit	$32M
– Athena II	Kodiak Island (?)	Approx. 325kg of Margin	$28M
– Delta II	SLC-2 at VAFB	Massive Performance Margin	$45M
– Kosmos	Baikonur & Plesetsk	1,400kg to 400km	$14M
• Launched FAISAT-2V s/c 9/23/97 out of Plesetsk, 825kg s/c			
– Proton Block DM	Baikonur	Massive Performance Margin	$30M
• Used for Iridium missions, also Asiasat 3, Inmarsat 3 F2, Telstar 5			
– Rokot	Baikonur	1,850kg to 300km	$3M
– Soyuz	Baikonur & Plesetsk	Massive Performance Margin	$36M
– Zenit	Sea Launch & Baikonur	Massive Performance Margin	$65M
– Tsyklon 3	Plesetsk	Massive Performance Margin	$11M
– Ariane 44L	Kourou	Massive Performance Margin	$82M
– Long March	Xichang	Massive Performance Margin	$10-25M

Note: Acquisition of foreign launch services requires Presidential waiver of National Space Policy.

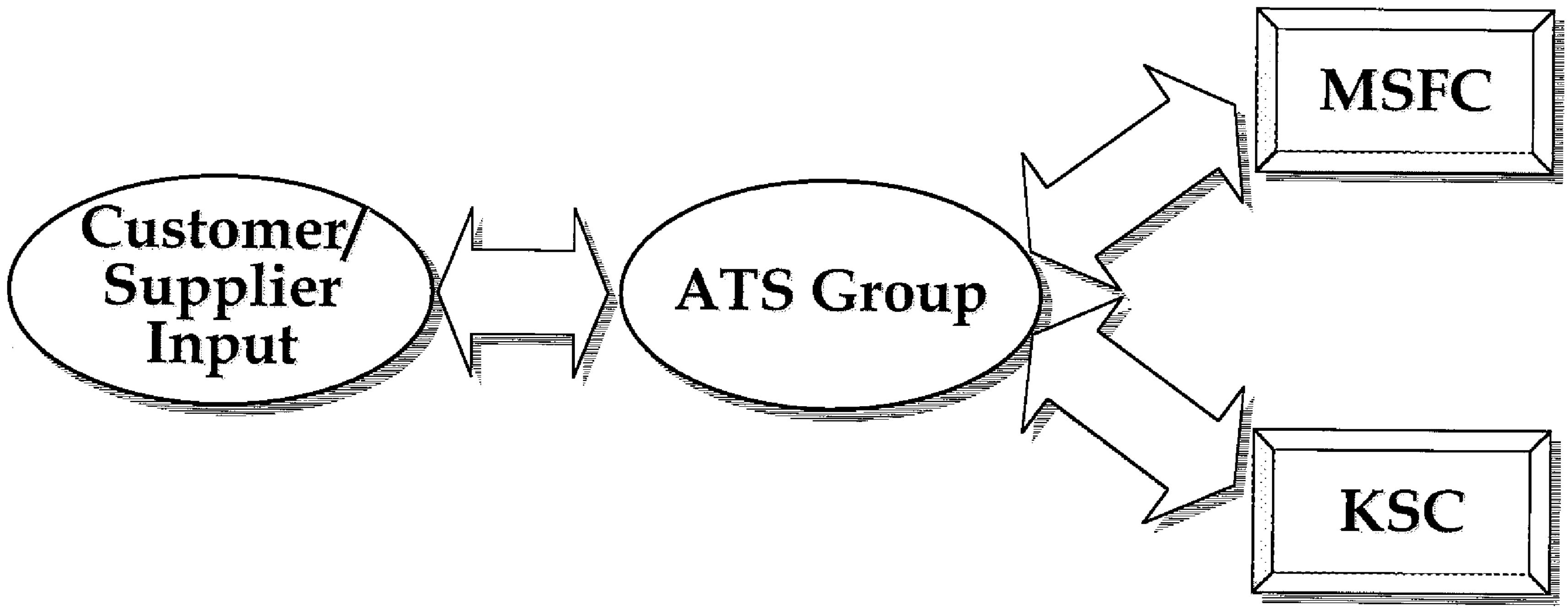
Potential Launch Vehicles
(Summary Sheet Example – all prices are estimates from public sources)

- Reusable/New Expendable Launch Vehicles
  - Kistler K-1 Woomera Rocket Range ~1,770kg to 600km, 94 deg $17M
    - First launch end of CY98/beginning of CY99
    - Contract with Space Systems/Loral for 10 launches - first launch 4Q CY99
    - ~$4,800/lb.
  - Beal B-2 Sombrero Island in Caribbean Massive Perf. Margin $?M
    - First launch scheduled for late CY99
  - Pioneer RocketPlane Take-off VAFB Requires Upper Stage on s/c $45M
  - Kelly Space Astroliner Take off EdwAFB Massive Perf. Margin (?) $9M (?)
    - Scheduled for start of commercial operations by mid-2001
  - Rotary Rocket Roton Mojave? Massive Perf. Margin $?M
    - Flight tests scheduled for CY99, commercial service mid CY00
    - $1,000/lb.

Project Support
(Implementation)

- Implementation Process
  - "The ATSA, to the extent requested by the GSFC Customer, will continue to support the Customer throughout the Implementation phase as the Customer's representative with the implementing access mode organization."
  - Project's single point of contact for access-related info and questions.
    - Allows Customer to concentrate on development and delivery of the payload (spacecraft and/or instrument).

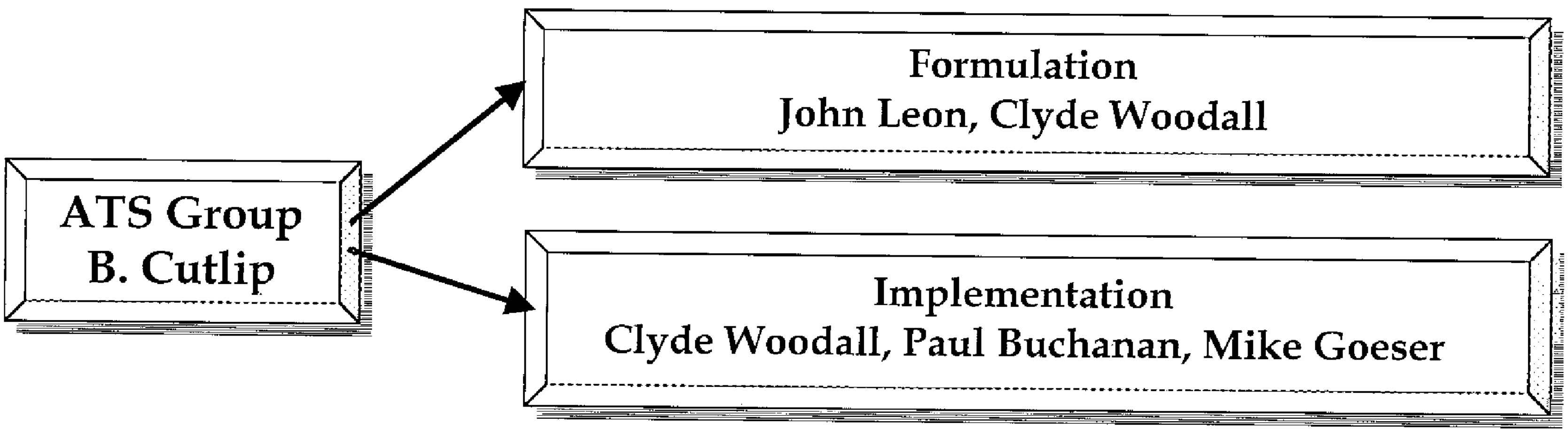
Change Advocacy



Example: Small orbit-raising propulsion system

Current ATS Workload

- Currently supporting
  - Twenty two missions in Pre-Formulation/Formulation
  - Sixteen missions in Implementation
  - Advocacy with MSFC and KSC (so far!)
  - Group Evolution - Web Page efforts, Partnerships, Briefings
    - Partnerships in work with KSC, MSFC, NRO/OSL Directorate, SMC/TE, and JSC



For Further Information, Please Contact:

ATS Group Leader

- Bill Cutlip

  William.E.Cutlip.1@gsfc.nasa.gov
  Voice: (301) 286-0438
  FAX: (301) 286-~~1696~~ 0232

Project Formulation Office

- Tom Taylor

  Thomas.S.Taylor.1@gsfc.nasa.gov
  Voice: (301) 286-8388
  FAX: (301) 286-0232

RSDO
Rapid Spacecraft Development Office

QUICK RIDE

ACQUISITION OVERVIEW

April 15, 1999

W. James Adams/401.5
301/286-1289
jim.adams@gsfc.nasa.gov

Rapid Spacecraft Development Office

RSDO Program Themes

- Mission Project Manager/PI are THE CUSTOMER!
- Contract for What Industry has to Offer
- Fixed Price Orders With Necessary Insight
- Performance Based Milestone Completion Payments
- Allow Mission Unique Modifications to Basic Offerings
- Fair Opportunity to be Considered in Rapid Selection Process
- Volume of Orders Needed to Maintain Interest
- No Protests Allowed by FAR 16.505 (a)(7)
- Lessons Learned Folded into Service for Next Customer

RSDO Rapid Spacecraft Development Office

History/Objectives

- Quick Ride is an Outgrowth of Rapid Spacecraft Acquisition
  - Multiple Task Order Contracts
  - Flight Service
- Provide a Variety of Low-Cost, Short Lead Time, Satellite Rides for Science Instruments:
  - Utilize Excess Space Available on Commercial Spacecraft
- Task Order Contracts with Commercial Firms That Will Permit Placing a Order Within 30 Days
- Secondary Objectives
  - Demonstrate a FAR Part 12 Commercial Acquisition
  - Explore the Use of On-Ramps

Rapid Spacecraft Development Office

Market Research & Sources

- Rapid Spacecraft Market Research in March 1997 Indicated Some Interest in Selling Excess Payload Space
- Sources Sought Synopsis Issued June 1997 with Responses from 7 Companies
- 2nd Sources Sought Synopsis Issued March 18, 1998 with Responses from 10 Companies
- Market Research Confirms Commercial Service Approach
- RFO Reviewed by Code M&OSTP

RSDO Rapid Spacecraft Development Office

Scope & Customer Base

- Scope
  - Define Rides Available Manifest and Minimum Order Time Before Launch
  - Carry Piggy-Back Secondary Instrument within Pre-Defined Parameters (Mass, Power, etc.)
  - Cost Range $2M-$4M for LEO Flight Service (GEO Goals $8M-$10M)
  - Fixed Price, Task Order Based Contracts
    - Interface Definition & Analyses
    - Integration & System Test
    - Launch
    - Initialization
    - 1 Year of On-Orbit Operations + Quarterly Options
  - Vendor Responsible for Obtaining all Export Licenses (Including the Secondary Payload)
  - Pre-Priced Accommodation Assessments (Studies)

RSDO
Rapid Spacecraft Development Office

Scope & Customer Base
(continued)

- LEO Technical Parameters
  - Mass 20Kg
  - Power 20 Watts
  - Data 2M Bits/Day
- Possible Customer Base
  - GISS/SPM, POEMS, UNEX, UESP, USAF Space Test Program, ESSP
  - NASA/GSFC, Other NASA Centers and Other Government Agencies (Consolidated Contract Initiative -- Intent to Procure Posted 3/31/98)

RSDO Rapid Spacecraft Development Office

Conditions, Constraints & Risks

Based on Market Research

- User Instrument Must be Fully Compatible with Satellite
- User Caused Integration Problems May Result in Loss of Ride
- User Instrument Must Be On Time Or We May Be Left Behind
- Mission Could be Delayed Due to Primary Mission Problems
- Commercial Operations of Satellite Take Precedence Over Instrument Operation
- Government Has No Oversight and Minimal Insight into Processes, Procedures and Flight Readiness. Decision to Launch Rests with Commercial Satellite Contractor

Rapid Spacecraft Development Office

Conditions, Constraints & Risks

- Short Lead Time to Identify Available Rides
- Flight Opportunities May Become Available Quickly -- Need to Identify and Complete Ride Selection Rapidly
- Instrument May Be Turned Off by Primary
- Payment Terms:
  - Technical Milestone Completion Based
  - Completion Criteria Defined in Task Order
- Financing Payments:
  - 60% of Task Order Value On-Orbit Performance Based
- NASA Conforms to the Market

Quick Ride Represents High Risk, Moderate Performance, Commercial Flight Opportunities at Very Low Prices

Rapid Spacecraft Development Office

Industry Response

- Received Only One Offer (Expected 4 to 7 Offers)
  - Final Analysis Inc.
  - BAFO Evaluated and Selection Made July 15, 1998
  - Contract Awarded to Final Analysis Inc.
    - Options for 10 Rides Over 3 Years
- Statement of Intention to Use On-Ramp from 4 Others

RSDO
Rapid Spacecraft Development Office

Using the Quick Ride On-Ramp

- Will Evaluate Unsolicited & Solicited Proposals Based On
  - Technical Minimums
  - Price Reasonableness

- If a Vender Offers a Ride Involving a Non-US Country Based Launch System RSDO will Notify Code M/OSTP
  - Proposal will be Evaluated and if Appropriate, Contract Awarded

RSDO Rapid Spacecraft Development Office

GEO Quick Ride

- NASA Desires to Promote Quick Ride on GEO Commercial Communications Missions
- Technical Feasibility Studies Underway
  - Lockheed Martin, Space Systems/Loral, Hughes Space and Communications, Orbital Sciences Corporation
  - Studies Wrap Up mid-May
- Results will be used to Assist Interested Satellite Owners to make Offers using Quick Ride On-Ramp
- Generic Interface Requirements Document for Science Teams Considering GEO Quick Ride

Spartan Project Overview

RideShare Conference

Donald E. Carson
Spartan Project Manager

April 15, 1999

E-mail: Don.Carson@gsfc.nasa.gov Homepage: http://spartans.gsfc.nasa.gov/

Spartan's Supporting Organizations

Long standing team with roots in NASA's origins
- Sounding rockets
- Get-Away-Special (GAS) Program
- Spartan
- Hitchhiker
- SSBUV
- Pegsat
- Small Explorer Program - SAMPEX, FAST, SWAS, TRACE, WIRE
  - Including instrument management

3 lines of business closely associated with our current activities
- SMEX
- Hitchhiker
- Spartan

Spartan Project

Result of Office of Space Science requirement for a transition capability between sounding rockets and orbital missions

- ⇨ Started early in the Shuttle program
- ⇨ Project drew from suborbital program designs, GAS program and existing MSFC bridge and attach mechanisms

Features reusable Shuttle-based carriers

Spartan is an in-house project drawing support from a mix of support service contractors and matrixed discipline support from GSFC organizations

What do we do - top level

Provide an enabling capability for Space & Earth Science and technology experiments

Provide a frequent, low cost flexible vehicle for technology validation and technology infusion

How do we do it

Design, build, integrate, fly *and reuse* Shuttle-launched free-flyers for the science and technology communities

What is the Spartan product line

The Project product line includes the Spartan 200 carrier and 4 Advanced Carriers in various states of development

- Spartan 200 - Autonomous 2 day mission, 1000 lb. instrument, flown 8 times
- Spartan 250 - Sp200 mechanical configuration with state-of-the-art avionics
  - Includes command and telemetry, 10 day mission
  - First mission, Sp251, funded by DoD, under development for flight in TBD
- Spartan Lite - Small <u>non-recoverable</u> satellite, 100 lb., 40 w. instrument
  - Shuttle side-wall mount offers frequent launch opportunities
  - Study went through carrier-only PDR/CDR
- Spartan 400 - Enabling capability for large instruments (1.5+ meter dia., 250+ w., 2000 lbs. class)
  - 1-3 year missions, orbit adjust/maintenance, recoverable/reusable
  - Generic carrier design has been through PDR
  - Phase A study for AF STP (nadir pointed) underway
  - Phase A study for NASA MIDEX effort, (solar pointed) underway
- Spartan 400/ISS serviced free-flyer - "entry level" Station serviced platform

In addition, the Project provides

<u>Customer Support</u>

- AO support - the project supports <u>all</u> interested, feasible proposers for NASA AOs including:
  - SMEX
  - UNEX
  - MIDEX
  - Discovery
  - ESSP
- We are a national resource for the science and technology communities
- Other user support as required - DoD, NRO, Code M

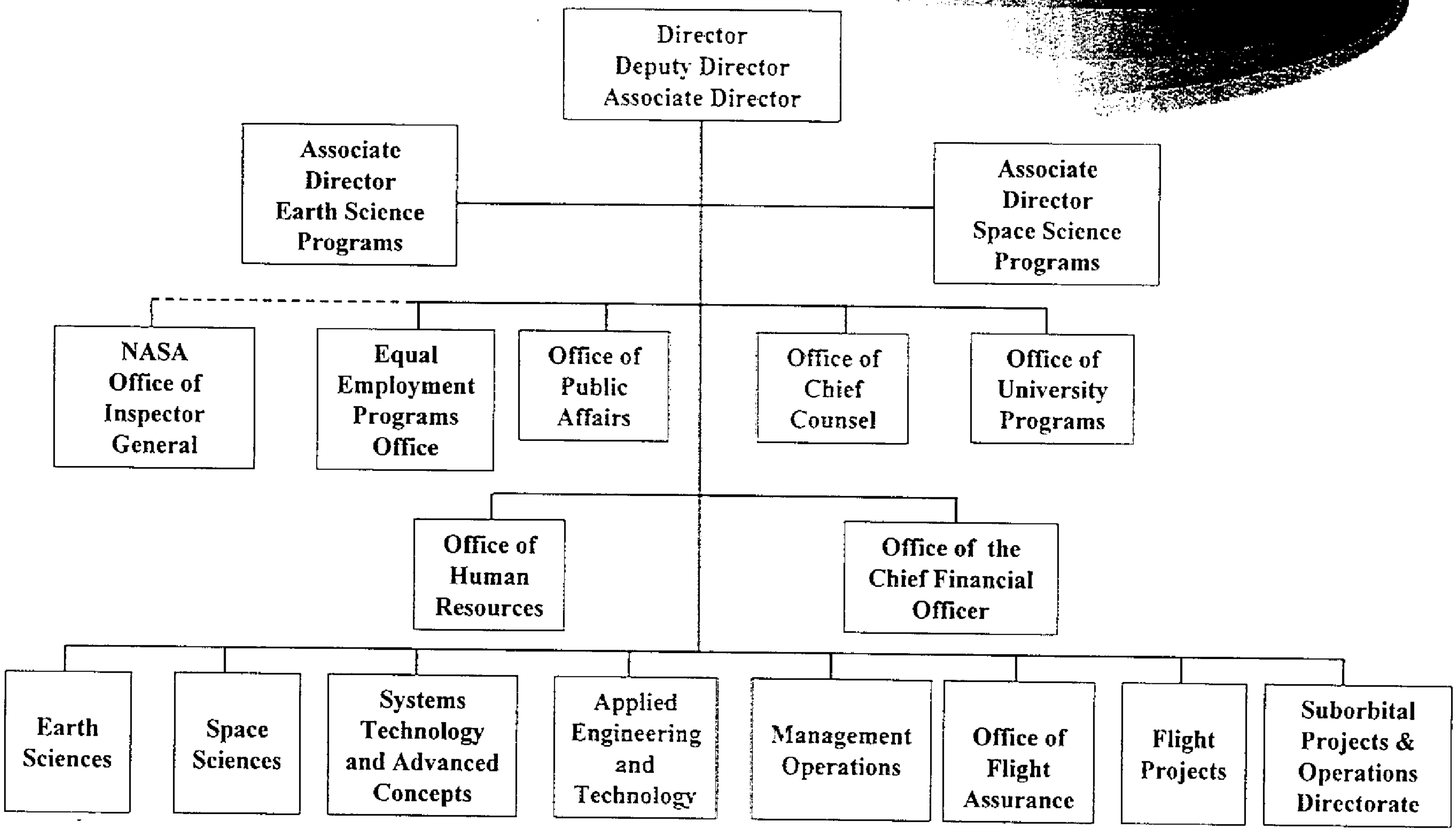
Summary Characteristics

CAPABILITY	SP400	SP 250	SP LITE
Mission Lifetime	1 - 3 yr.	2 - 12 days	up to 1.5 yr.
Instrument Weight	2000 lbs.	1100 lbs.	100 lbs.
Instrument Volume	60 in. diam. 160 in. length	60x50x30 in. 120 in. x 22 in. tube	14 in. diam. 40 in. long
Instrument Power	250 - 750 W	90 W	40 W
Solar Arrays	Deployed, Articulated, Fixed	Deployed, Fixed	Fixed
Uplink/ Downlink	2 kbps/2 Mbps	2 kbps/2 Mbps	2 kbps/2Mbps
Instrument C&DH I/F	1553 or RS-422	1553 or RS-422	1553 or RS-422
Pointing Accuracy	Arc-second	Arc-second	Arc-second
Retrievable	Yes	Yes	No
Launch Vehicle	Shuttle	Shuttle	Shuttle/ELV

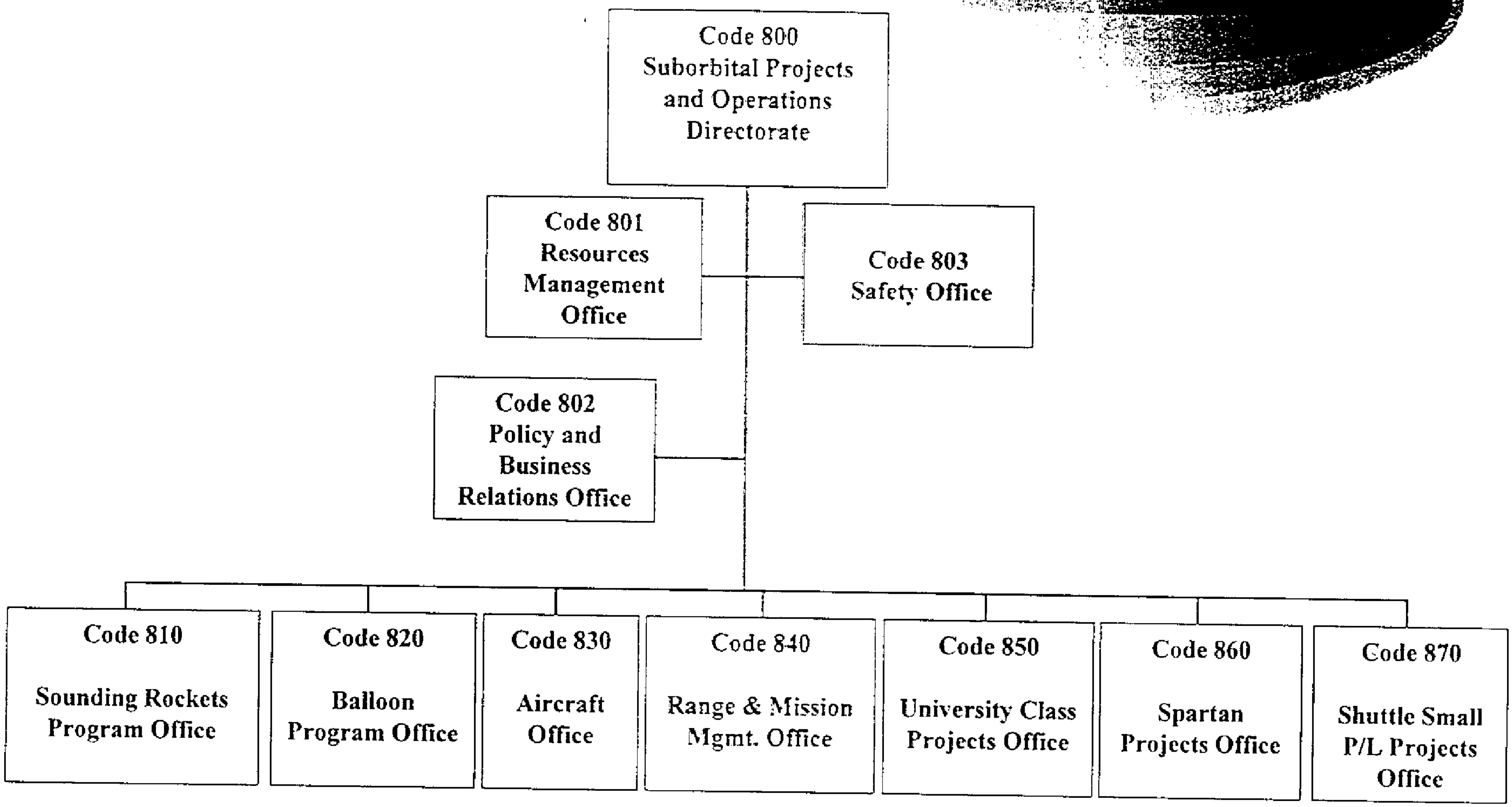
Spartan Mission List

Spartan number	Type of Mission	PI/Institution	Status
101	High Energy Astrophysics	Cruddace/NRL	Flown 6/85 (STS-51G)
201-01	Solar Physics	Kohl/SAO, Fisher/GSFC	Flown 4/93 (STS-56)
201-02	Coordinated observations - Ulysses	Kohl/SAO, Fisher/GSFC	Flown 9/94 (STS-64)
201-03	Coordinated observations - Ulysses	Kohl/SAO, Fisher/GSFC	Flown 9/95 (STS-69)
201-04	Calibration Flight - SOHO	Kohl/SAO, Fisher/GSFC	Launched 11/97 (STS-87)
201-05	Calibration Flight - SOHO	Kohl/SAO, Fisher/GSFC	Flown 10/98 (STS-95)
203	UV Observation of Comet Halley (Lost with Challenger)	Barth/LASP	Lost 1/86 (STS 51-L)
204	UV Astronomy (Stellar)	Carruthers/NRL	Flown 2/95 (STS-63)
206 (OAST-Flyer)	Technology Experiments	Lorentson, Bauer/GSFC Brown/JSC,McCaughey/UMd	Flown 1/96 (STS-72)
207 (IAE)	Inflatable Antenna Experiment	Veal/L'Garde	Flown 5/96 (STS-77)
251 (XS-10)	Micro-sat technology demo	DOD	TBD

GSFC Organization



Suborbital Projects & Operations Directorate



Shuttle Small Payloads Project Office Overview

S. Chris Dunker
Shuttle Small Payloads Project Office Chief
NASA Goddard Space Flight Center
http://sspp.gsfc.nasa.gov

April 15, 1999

Outline

- Shuttle Small Payloads Project Office (SSPPO) Introduction
    - Program Sponsors
    - Current Manifest
- Hitchhiker (HH) Program
    - Hitchhiker-Junior (HH-Jr) Program
- Get Away Special (GAS) Program
- Space Experiment Module (SEM) Program
- Program Costs
- Future Enhancements

SHUTTLE SMALL PAYLOADS PROJECT OFFICE
INTRODUCTION

Shuttle Small Payloads Project Office

- NASA's Goddard Space Flight Center (GSFC) Shuttle Small Payloads Project Office (SSPPO) operates the Hitchhiker, Hitchhiker-Jr., Get-Away-Special (GAS) and Space Experiment Module (SEM) Projects for NASA's Office of Space Flight.

- Contacts:

  - Payload Carriers Program, Code VA-A, KSC
    Charles Sawyer, Jr., (407) 867-4840

  - Hitchhiker/GAS Program Coordination, Code MO, HQ
    John Castellano, (202) 358-4423

  - Shuttle Small Payloads Project Office, Code 870.G, GSFC
    Chris Dunker, (301) 286-4271

Shuttle Small Payloads Project (continued)

- ***Hitchhiker Payloads***:
  - Carrier provides for Orbiter side-mounting or cross-bay mounting options
  - Experiments may be mounted in canisters, side plates, or top-mounted pallets
  - Standard, easy-to-use mechanical and electrical interfaces
  - Orbiter-provided power, command and data services available

- ***Hitchhiker-Jr Payloads***:
  - Reduced version of Hitchhiker available for canister customers not requiring ground communications services

- ***GAS Payloads***:
  - Self-contained payloads mounted in canisters only
  - Customer-provided power (battery) and data system required
  - Tertiary payload queue
  - Cannot require shuttle attitudes

- ***SEM Payloads***:
  - Up to ten SEM Experiment Modules integrated into a single canister
  - SEM-provided structural support, power, command and data services
  - Tertiary payload queue
  - Cannot require shuttle attitudes

Active GSFC Shuttle Small Payloads (as of March 1999)

• STS-96:	STARSHINE SVF-02	
• STS-101:	SEM-06 MARS	
• STS-105	HEAT	CAPL3 AMTEC-AWCS SIMPLESAT CONCAP-IV ACE-Jr. GAS (TBD x 2)
• STS-107	TAS-04/ISIS	ISIS GAS (TBD x 1) SEM (TBD x 1)

HITCHHIKER PROGRAM

Hitchhiker Program Description

- The Hitchhiker Program
  - Initiated by NASA's Office of Space Flight in 1984
  - Quick reaction and low cost shuttle carrier service for small payloads
  - Simple, standard carrier to orbiter interfaces
  - Standard, user-friendly, carrier to customer interfaces
  - Reduce payload unique integration effort
  - Reduce lead time and recurring cost

- The Hitchhiker carriers consist of modular equipment designed for either side-mounting or cross-bay mounting in the shuttle payload bay

- Hitchhiker is sponsored by the NASA/HQ Office of Space Flight
  - No cost to a NASA user provided only standard services are required
  - Excess (optional) services are funded by the customer

- Hitchhikers are generally shuttle secondary payloads. Highly complex Hitchhiker carriers have also been manifested as primary payloads

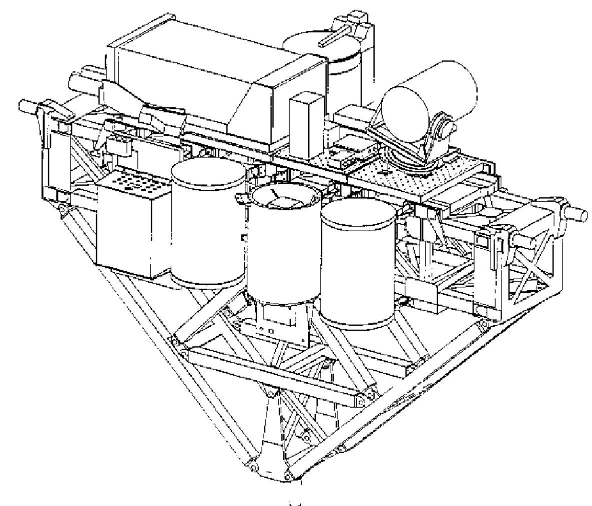
- 24 Hitchhiker missions have been flown

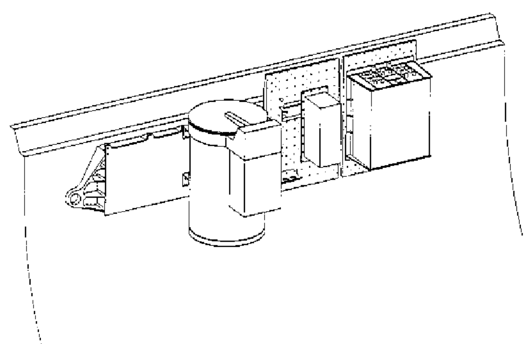
Hitchhiker Mechanical Accommodations

- The Hitchhiker carriers consist of modular equipment designed for either side-mounting or cross-bay mounting in the shuttle payload bay

- Hitchhiker mechanical mounting provisions:

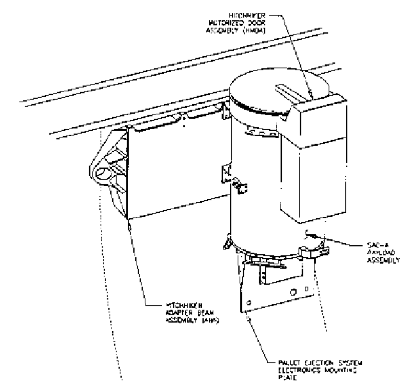
  - 5 Cubic Ft. Canisters – Max 200 lb. Payload Weight
  - 19" diameter x 28" height
  - Motorized Door Option
  - Side Mount Plate – Max 305 lb. Payload Weight
  - Top Plate – Max 600 lb. Payload Weight



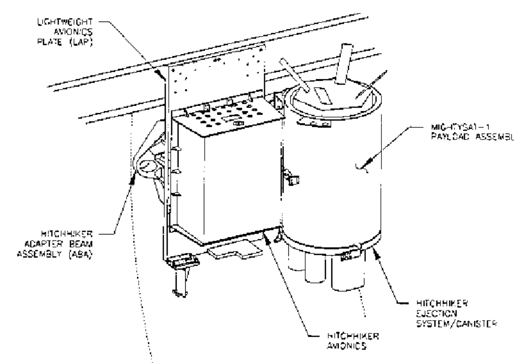


Hitchhiker Ejection Systems

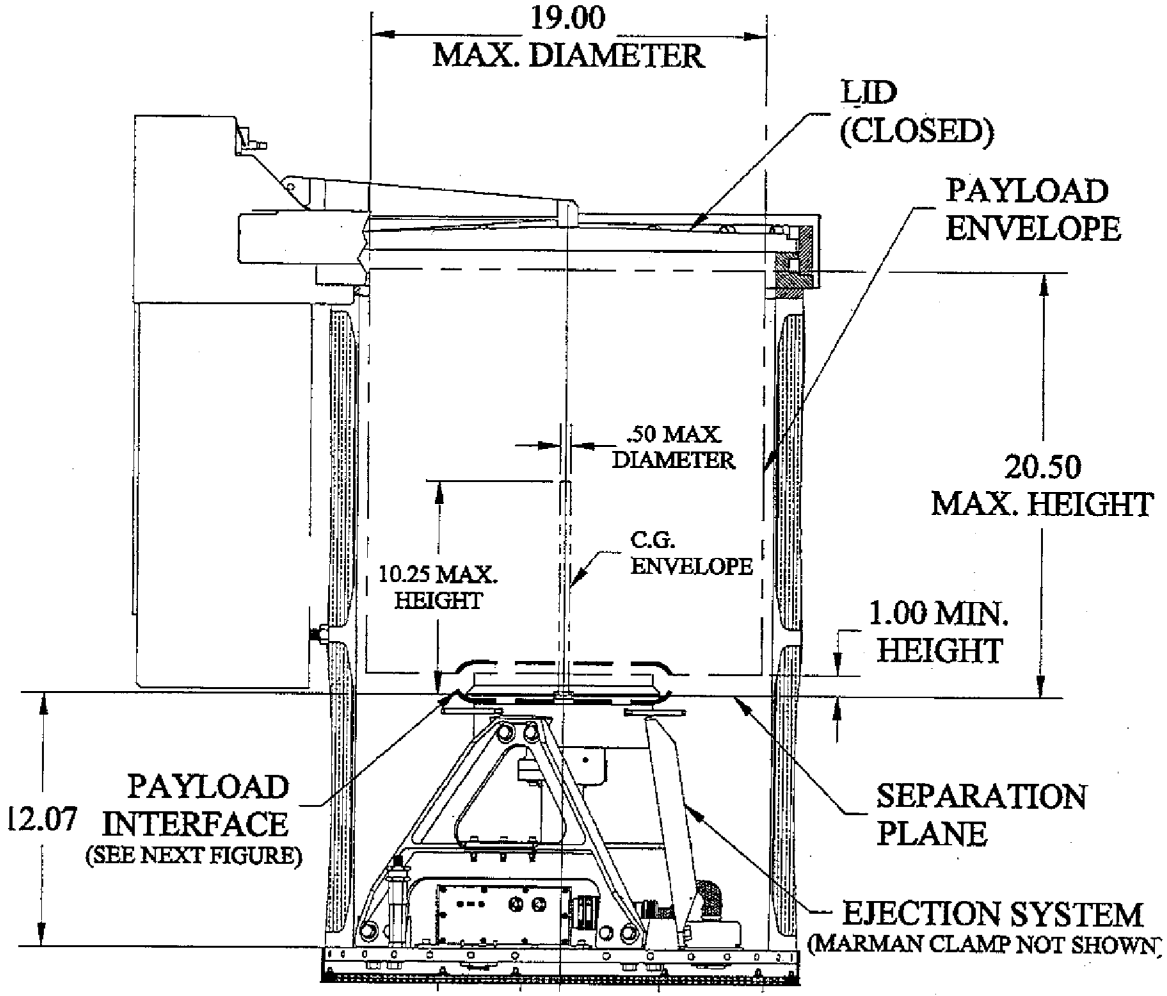
- Two Hitchhiker Ejection Systems may be used to launch small, non-hazardous customer payloads into shuttle orbit
  - Hitchhiker Ejection System (HES)
  - Pallet Ejection System (PES)



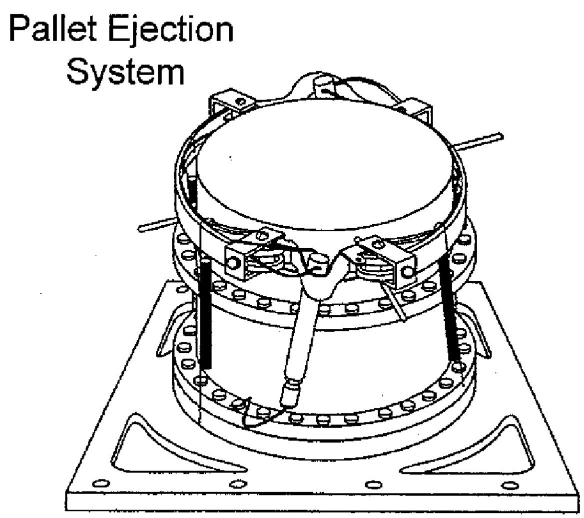
- Payloads up to 150 lb (68 kg), 19 inches (48 cm) in diameter and 20 inches (50 cm) high may be accommodated on a nine-inch clamp band launcher housed in a canister with or without a Hitchhiker Motorized Door Assembly
- Payloads up to 150 lb (68 kg) but with larger diameters can be launched on a Hitchhiker PES off the top of a cross-bay carrier
- No electrical connections to payloads are provided
- Neither HES nor PES provides for satellite spin-up
- HES has been used to launch GLOMR, NUSAT, BREMSAT, PAMS and MightySat 1
- PES has been used to launch SAC-A and PANSAT



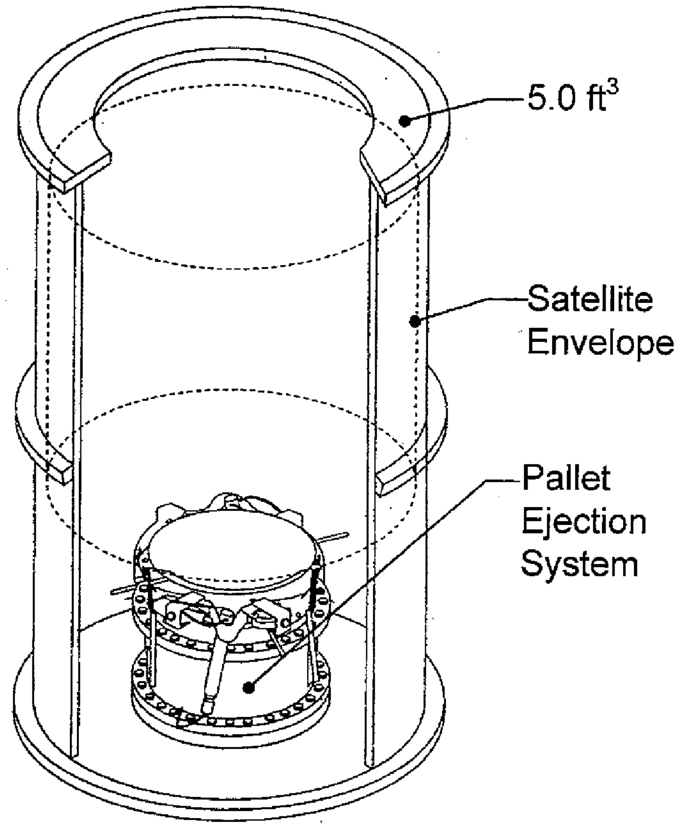
Hitchhiker Ejection System Payload Envelope



Pallet Ejection System (PES)



Pallet Configuration

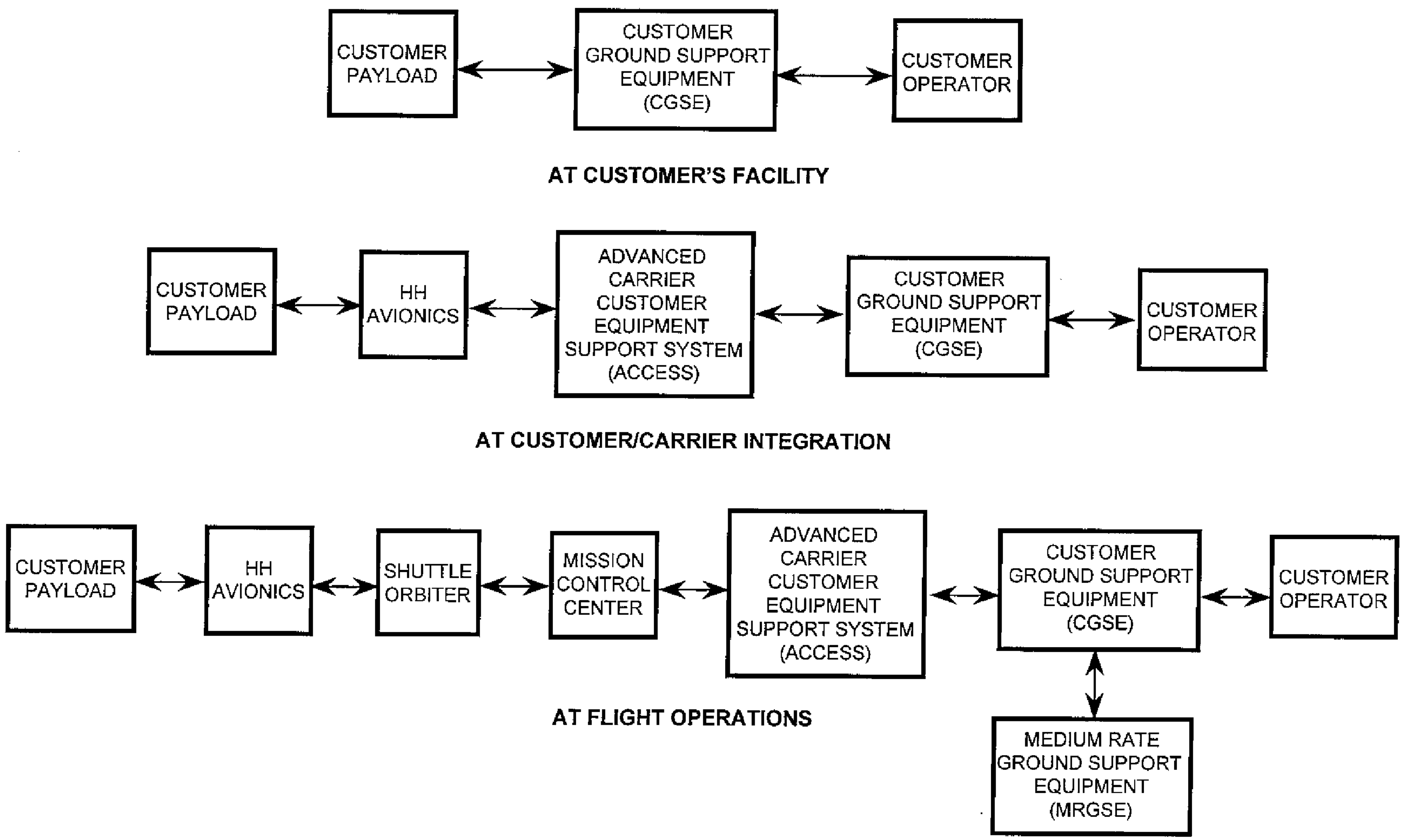


Can Configuration

Hitchhiker Electrical Accommodations

- The current Hitchhiker Avionics System
  - Eight standard electrical interface "ports" for customer payloads
  - Each port provides the following:
    - 28V Power, Two 10A Circuits, up to 500W
    - Ground Command Interfaces
    - Time Signal
    - Low-rate Data Channel, up to 1200 Baud Downlink
    - Medium Rate Data Channel up to 1.4 MB Downlink
- Additional electrical services are optional including CCTV interface for on-board recording and downlink, or for crew display and control interface
- Payloads are operated from a Payload Operations Control Center (POCC) located at GSFC

Hitchhiker Transparent Data System



Hitchhiker Thermal Experiment Requirements

- Each experimenter is responsible for the thermal design of their experiment

- Each experimenter will provide to HH thermal analysis data that includes the following information:
  - A description of all surface coatings and multi-layer insulation (MLI) blankets
  - A **reduced** geometric and thermal math model of the experiment (approximately 50 surfaces and 20 nodes)
  - Temperature limits for all nodes in the thermal model for operating, non-operating and survival/safety cases
  - The size and location of heaters and the setpoints for the thermostats

- Each experimenter is responsible for providing their own thermal control coatings, MLI blankets, heaters and thermostats. HH provides the coatings and blankets on our plates, pallets, cans, and avionics

Hitchhiker Thermal Deliverables

- Thermal Models
  - Experiment Reduced Thermal Models to be delivered to HH at L-15 months
  - Payload Reduced Thermal Models to be delivered to JSC at L-12 months
  - Payload Temperature Predictions and Capabilities to be delivered to JSC at L-12 months

- Using the data supplied in the thermal models and reports, HH will provide inputs to the:
  - Orbiter ICD Thermal Zone Chart and Surface Properties
  - PIP Capabilities Tables
  - Annex 2 Thermostatic Equipment Tables
  - Integrated Safety Analysis
  - Flight Rules
  - Mission Timeline Analysis

Hitchhiker Integration and Operations

- Ground operations flow at GSFC:
  - Hitchhiker customer equipment is typically integrated to the carrier at GSFC
  - System-level functional tests, EMI tests and telemetry tape tests are performed prior to shipping the integrated payload to KSC
  - POCC mission simulations conducted from the GSFC POCC
  - Customers provide personnel and Ground Support Equipment to operate their payloads during integration, mission simulations and flight
  - Ready for Shipment

- Ground operations flow at KSC:
  - Post-ship functional tests, thermal coating close-outs and sharp-edge inspections are performed at a KSC "off-line" Payload Processing Facility (PPF)
  - Orbiter installation occurs at the Orbiter Processing Facility (OPF) for horizontally processed payloads: at the Launch Pad for vertically-processed payloads
  - Orbiter Interface Verification Testing (IVT), final close-out of Remove-Before-Flight items, and a final sharp-edge inspection are performed at the Launch Pad
  - Ready for Launch

Hitchhiker Shuttle Process Scenario (Months)

L-24 Customer Organization Submits Form 1628

L-24 Customer Submits CPR to GSFC/SSPP

L-23 Customer Accommodation Meeting at GSFC

L-20 Customer Submits Preliminary Safety Data

L-7 Customer Submits Final Safety Data

L-6 Customer Hardware Delivered to GSFC

L-5 Customer/carrier Integration Completed

L-4.5 Hitchhiker Payload Shipped to Launch Site

L-3 Sidewall Hitchhiker Payload Installed in Orbiter

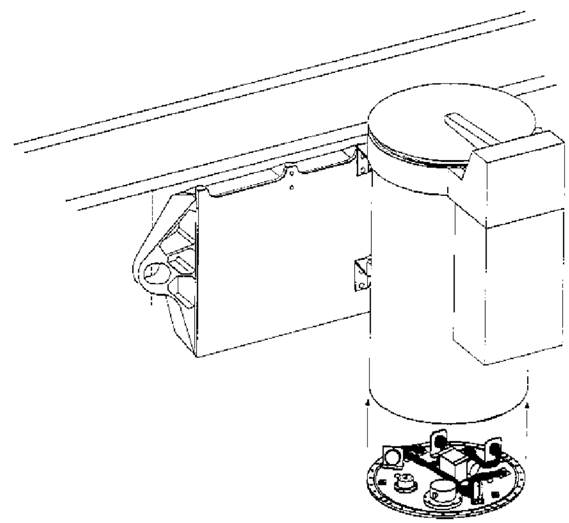
L=0 Launch

L+1 Customer Equipment Returned

HITCHHIKER-JUNIOR (HH-JR) PROGRAM

HH-Jr Program Description

- A reduced version of Hitchhiker (HH-Jr) is available for canister customers who do require ground communicaitons services
- Mechanical and electrical Interfaces are similar to GAS
- Payloads are controlled by the crew during the mission. HH-Jr carrier provides display of carrier and customer engineering data (temperature, pressure, etc.) and has extensive crew command capability
- Approximately 100 W orbiter power available.



HH-Jr Shuttle Process Scenario (Months)

L-18 Customer Organization Submits Form 1628

L-18 Customer Submits CPR to GSFC/SSPP

L-17 Customer Accommodation Meeting at GSFC

L-16 Customer Submits Preliminary Safety Data

L-6 Customer Submits Final Safety Data

L-5 Customer Hardware Delivered to GSFC

L-4 Customer/Carrier Integration Completed

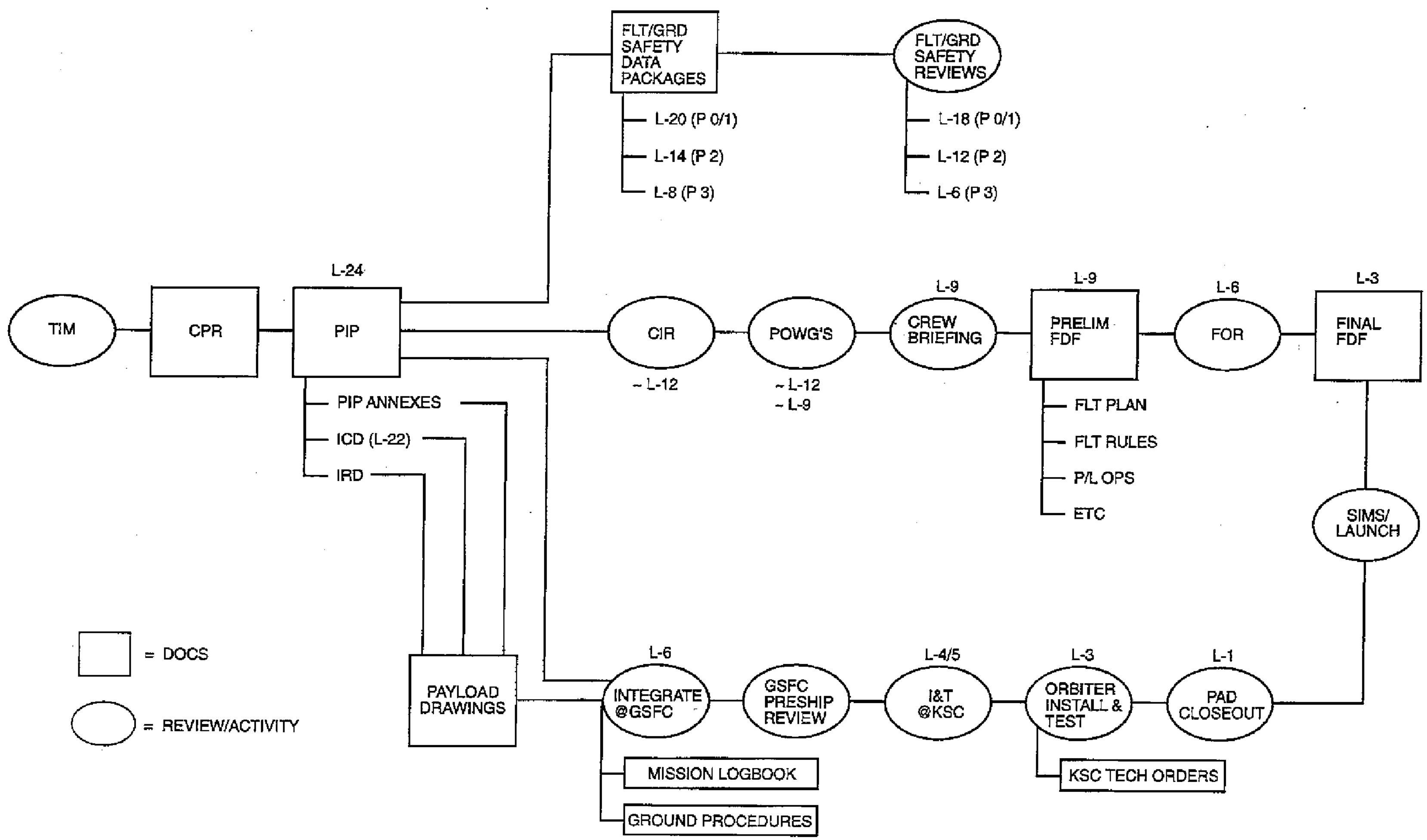
L-4 Payload Shipped to Launch Site

L-3 Payload Installed in Orbiter

L=0 Launch

L+1 Customer Equipment Returned

The Hitchhiker/Shuttle Process



Typical Hitchhiker Payload Document Deliverables

Prepared by GSFC/JSC with Experiment Inputs:

Payload Integration Plan (JSC)

PIP Annexes (JSC - inputs to all annexes required prior to CIR)

Annex 1	Payload Data Package Annex
Annex 2 Parts 1,2	Flight Planning Annex
Annex 3	Flight Operations Support Annex (has been replaced by the Payload Operations Workbook)
Annex 4	Orbiter Command and Data Annex
Annex 5	Payload Operations Control Annex
Annex 6	GSFC/Swales (replaced by Interface Control Annex)
Annex 7	Training Annex (not typically required)
Annex 8	Launch Site Support Plan
Annex 9	Payload Verification Requirements Annex
Annex 11	EVA Annex (not typically required)

Orbiter Interface Control Document (ICD), prepared by Boeing North America

Orbiter Installation Requirements Document (IRD), prepared by Boeing North America)

Experiment to Carrier ICD's

Mission Operations Documentation

Typical Hitchhiker Payload Document Deliverables (continued)

Prepared by Experiment Organization and submitted to GSFC:

Customer Payload Requirements (CPR) Document
Flight and Ground Safety Data Packages
Reduced Thermal Model
Thermal Report
Fracture Control Implementation Plans
Fracture Control Summary
Drawing Package
Command Plan (draft - L-4 to L-6 mos, Final L-1 week.)
Nominal and Contingency Experiment Flight Operations Procedures
Technical Operating Procedures
PAO Experiment Summary and Line Art

GET AWAY SPECIAL (GAS) PROGRAM

GAS Program Description

- The GAS Program
  - Initiated by NASA's Office of Space Flight in the mid-1970's
  - Simple, Standard Carrier to Orbiter Interfaces
  - Standard, User-friendly, Carrier to Customer Interfaces
  - Minimum crew activity
  - No orbiter pointing requirements allowed
  - Opportunity manifesting only
- GAS carrier consists of 5 and 2.5 cubic foot canisters designed for either side-mounting (Adapter Beam Assembly) or cross-bay mounting (GAS Bridge Assembly) in the Shuttle Payload Bay
- GAS is sponsored by the HQ Office of Space Flight
  - First-in First-out Queue System
  - $27,000 cost to Non-NASA users
  - No Cost to a NASA User Provided Only Standard Services Are Required
- GAS payloads are always Shuttle tertiary payloads.
- 448 reservations; 28 customers have payloads in work

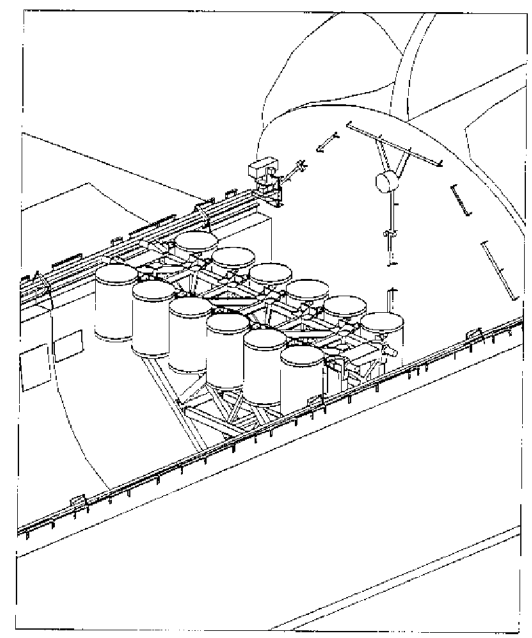
GAS Mechanical Accommodations

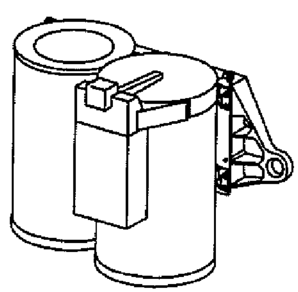
- The GAS carrier consists of 5 and 2.5 cubic foot canisters designed for either side-mounting (Adapter Beam Assembly) or cross-bay mounting (GAS Bridge Assembly) in the Shuttle Payload Bay

- GAS Mechanical Mounting Provisions:

  - 5 Cubic Ft. Canisters – Max 200 lb. Payload Weight
  - 19" dia X 28" high
  - Motorized Door Option

  - 2.5 Cubic Ft. Canisters - Max 150 lb payload weight
  - 19" dia X 14" high





GAS Electrical Accommodations

- Electrical System
  - No orbiter power, data or command interfaces
  - Power must be provided via a user-supplied battery
  - Three crew-controlled (laptop) relays activate and deactivate GAS payloads
  - Simple pre-programmed control functions
  - Baroswitch to activate limited payload functions

GAS Thermal Experiment Requirements

- Each experimenter is responsible for the thermal design of their experiment
- Sealed GAS canister typically provide a fairly benign thermal environment, thereby significantly reducing the complexity of the thermal analysis
- Required data still includes the following information:
  - A description of all surface coatings and multi-layer insulation (MLI) blankets
  - A **reduced** geometric and thermal math model of the experiment (approximately 50 surfaces and 20 nodes)
  - Temperature limits for all nodes in the thermal model for operating, non-operating and survival/safety cases
  - The size and location of heaters and the setpoints for the thermostats
- Each experimenter is responsible for providing their own internal thermal control techniques. HH provides the coatings and blankets on the canister exterior.

SPACE EXPERIMENT MODULE (SEM) PROGRAM

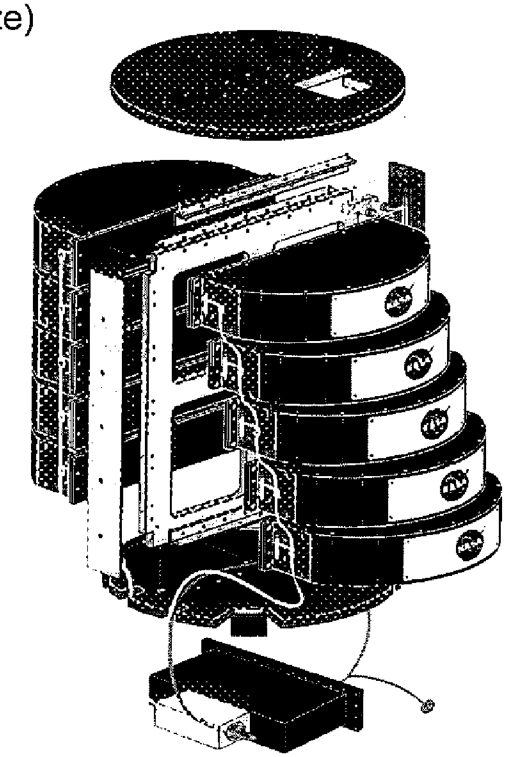
SEM Program Description

- The SEM Program
  - NASA educational initiative sponsored by the GSFC SSPPO
  - Provides nationwide educational access to space for Kindergarten through University level students
  - Experiments are created, designed, built and implemented by the students
  - Two standard mounting interface optionsSimple, Standard Carrier to Orbiter Interfaces
  - Carrier-provided power, command and data storage options
- SEM carrier consists of a 5 cubic foot canister housing up to ten separate SEM Experiment Modules
- SEM Is sponsored by the GSFC SSPPO
  - First-in First-out Queue System
  - No cost to qualified educational institutions
- SEM payloads may be Shuttle secondary or tertiary payloads
- Six SEM payloads (fully loaded canisters) have flown

SEM Mechanical Accommodations

- The SEM carrier consists of a standard 5 cubic foot canister containing ten separate SEM Experiment Modules

- SEM Experiment Module Mechanical Mounting Provision:
  - Use of NASA-provided Space Capsules to contain passive test articles
    - Clear, 1' x 3" sealed plastic vials (0.5" capsule neck size)
    - Up to 22 vials may be packed in an individual Experiment Module using silicon foam cushion
  - Use of the SEM Experiment Module cover as an Experiment Mounting Plate (EMP)
    - The experiment envelope is precisely defined by the area delineated on the inboard surface of the EMP and a depth of 3.25" perpendicular from the surface of the EMP
    - Experiments are designed to be mounted to the surface of the EMP using NASA-provided integration hardware



SEM Electrical Accommodations

- SEM Active Experiments:
  - Power, command and data recording capabilities provided by the SEM Module Electronics Unit (MEU)
  - One crew-controlled (laptop) relay activates and deactivates a SEM canister
  - Temperature profile monitoring capability available via NASA-provided thermistors
  - Simple pre-programmed control functions
  - On-board data recording only; no telemetry feedback
- SEM Passive Experiments:
  - Do not require power, command and data recording capabilities

SEM Thermal Experiment Requirements

- Each experimenter is responsible for the thermal design of their experiment
- Each experimenter is responsible for providing their own internal thermal control techniques. HH provides the coatings and blankets on the canister exterior
- Temperature profile monitoring is available post-flight, via NASA-provided thermistors

PROGRAM COSTS

Program Costs

- ***Hitchhiker***
  - Sponsored by the Office of Space Flight, KSC Payload Carriers Program Office
  - No cost to NASA users provided only standard services are required
  - Standard services are described in the Hitchhiker "Customer Accommodations and Requirements Specifications (CARS)" document
  - Optional services assessed on a case-by-case basis
  - DoD payloads: approximately $400K per <u>experiment</u>. Funded by USAF Space Systems Division JSC/ZR for standard integration services
  - Foreign reimbursable: shuttle mission cost X .0078 per <u>mounting</u> slot; previously about $1.2M (as of 1992)

- ***GAS***
  - Sponsored by the Office of Space Flight, KSC Payload Carriers Program Office
  - No cost to NASA users provided only standard services are required
  - $27,000 cost to non-NASA users ($10,000 cost for U.S. educational institutions)
  - First-in First-out queue system

- ***SEM***
  - Sponsored by the Office of Space Flight, KSC Payload Carriers Program Office
  - No cost to qualified educational institutions
  - First-in First-out queue system

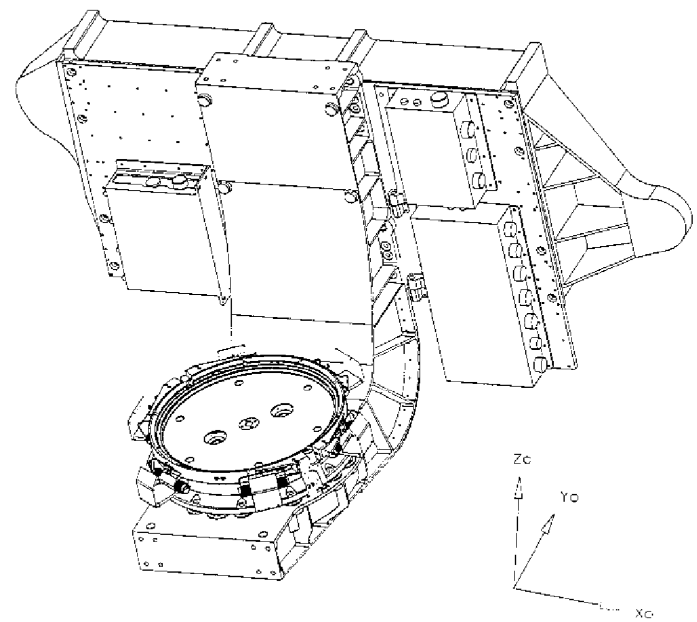
FUTURE ENHANCEMENTS

Future Enhancements

- ***Advanced Carrier Electronics (ACE)***
  - Supports up to 61 experiments
  - Supports PDI data rate: 8, 16, 32 Kbit/sec (configurable during mission)
  - Supports medium rate data archiving and playback during mision (up to 1 Mbit/sec)
  - Supports medium rate data up to 1.8 Mbit/sec
  - Provides system redundancy
  - Provides time tagged command / pre-stored command capabilities
  - Provides enhanced experiment interface

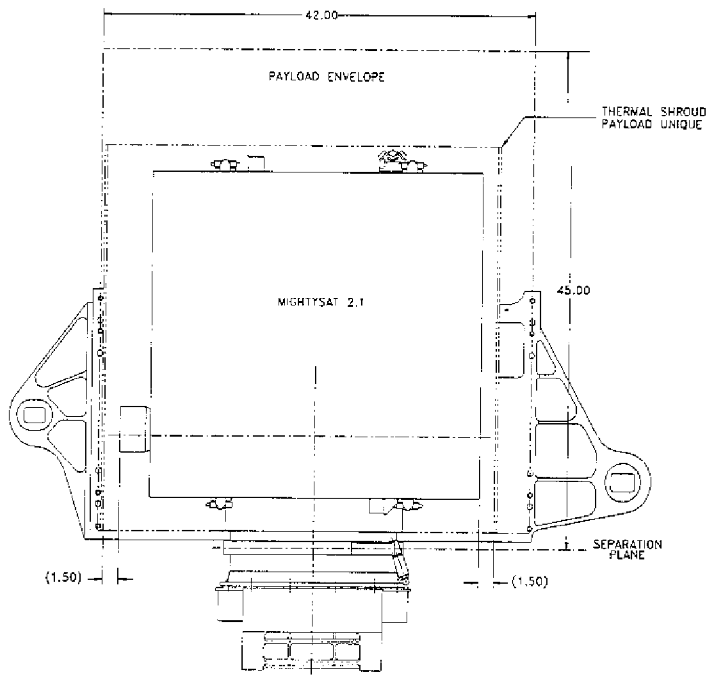
Future Enhancements

- ***Shuttle Hitchhiker Ejection System (SHELS)***
  - Co-sponsored development by NASA/GSFC and DoD (USAF SMSC/OL-AW)
  - Side-mounting shelf designed to eject up to a 400 lb (maximum) satellite from the Shuttle Payload Bay
  - Center of gravity 24 inches above the separation plane; +/- 0.25 inches off ejection axis centerline
  - Payload envelope:
    - 42.0" (orbiter +/-x)
    - 26.0" (orbiter +/-y)
    - 45.0" (orbiter +/-z)
  - Power and data umbilical available
  - 280 Watts radiated heater power if no umbilical

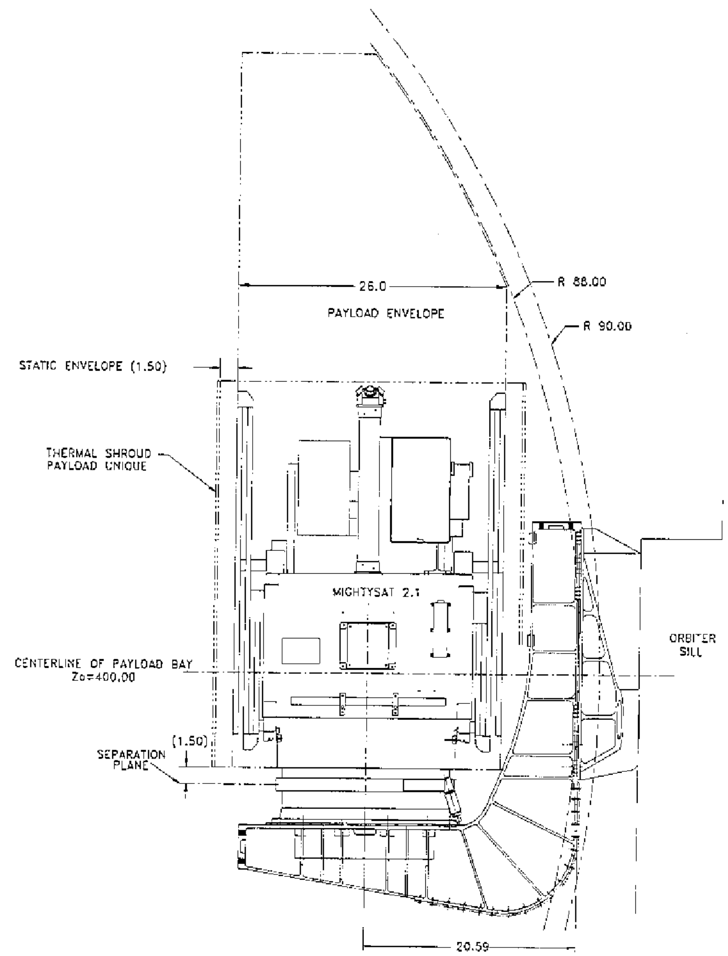


Future Enhancements

- ***Shuttle Hitchhiker Ejection System (SHELS) Payload Envelope***



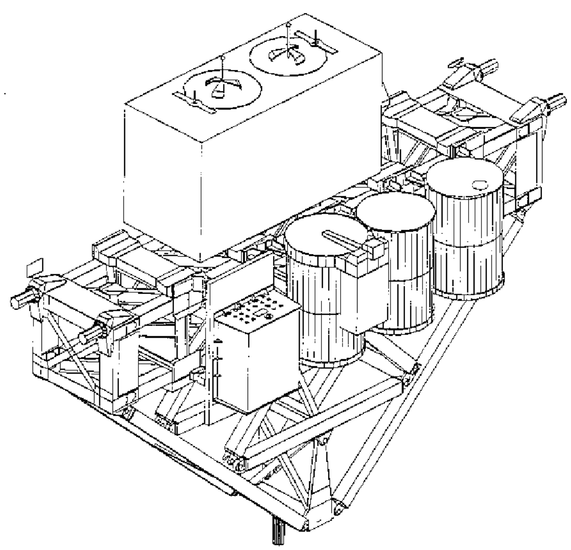
SIDEWALL ENVELOPE LOOKING AT ORBITER SILL

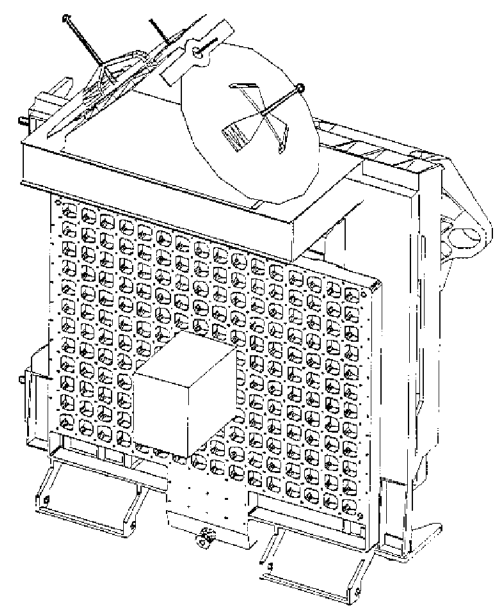


SIDEWALL ENVELOPE LOOKING DOWN THE ORBITER BAY

Future Enhancements

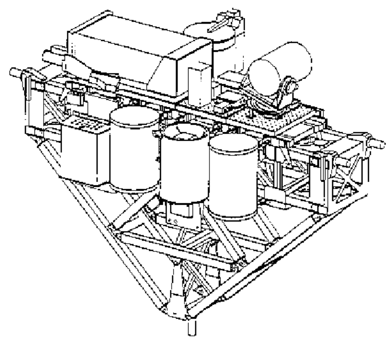
- ***International Space Station (ISS) Hitchhiker External Attached Payload Concepts***
  - ISS will be able to accommodate carriers such as Hitchhiker and GAS
  - SSPP concept provides carrier systems with standard Hitchhiker-type interfaces to allow flight of existing instruments
  - Carrier system to be accommodated on Express Pallet, Japanese Experiment Module, and other mounting options to be determined

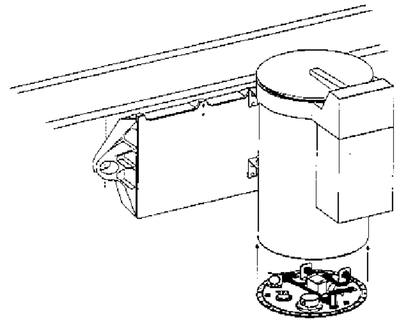


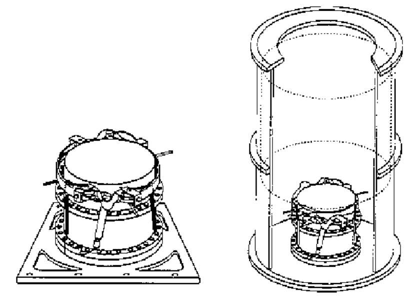


Summary Comparison of SSPP Projects

Comparison of Hitchhiker, Hitchhiker-Jr., GAS, CAP and SEM Carrier Requirements

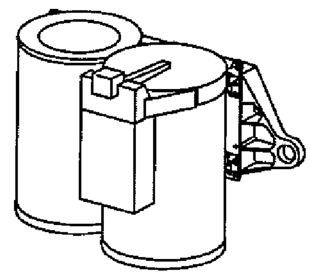


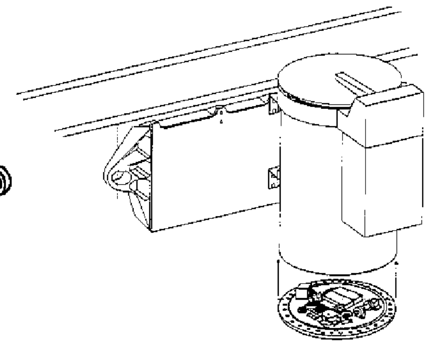


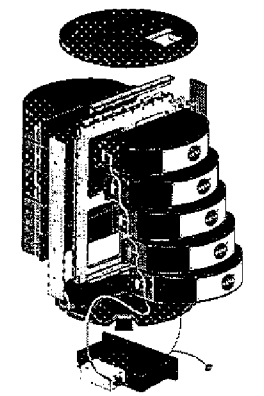


CAPABILITY	HITCHHIKER	HITCHHIKER-JR	SEPARATION SYSTEMS **HH Ejection System (HES)** **Pallet Ejection System (PES)**
Payload Category	Primary/Secondary	Secondary	Secondary
Max Customer Weight (lb)	3000	200	150
Payload Mounting	Canister; Side Plate; Single Bay Pallet (SBP); Double Bay Pallet (DBP)	Canister	HES:Canister (Door/No Door) PES: Canister (Door/No Door); Single Bay Pallet (SBP); Double Bay Pallet (DBP)
Subsystems	PWR, CMD/TLM HTR PWR	PWR, Limited CMD/TLM HTR PWR	No PWR, No CMD/TLM HTR PWR (Canister Walls)
Supplied Power (watts)	1500W	100W	No
Uplink Commands	Yes	No	No
Downlink Data (max)	1.4 Mb/s	No	No
Crew Control	Option	PGSC/BIA	SSP
Crew Display	Option	Yes	Yes
Payload Unique Attitudes	Yes	Yes	Yes

Comparison of Hitchhiker, Hitchhiker-Jr., GAS, CAP, and SEM Carrier Requirements







CAPABILITY	GAS	CAP	SEM
Payload Category	Tertiary	Secondary	Tertiary
Max Customer Weight (lb)	200	200	6 per module 60 per payload
Payload Mounting	Canister	Canister	Module
Subsystems	No	No	Battery, Fuse Box, Support Structure
Supplied Power (watts)	No	No	600W
Uplink Commands	No	No	No
Downlink Data (max)	No	No	No
Crew Control	3 Relays (APC)	PGSC/BIA	1 Relay (APC)
Crew Display	PGSC/BIA	PGSC/BIA	PGSC/BIA
Payload Unique Attitudes	No	Yes	No

Flight Assignment Working Group
Planning Manifest

MightySat Program

Information Briefing for NRO Rideshare Conference

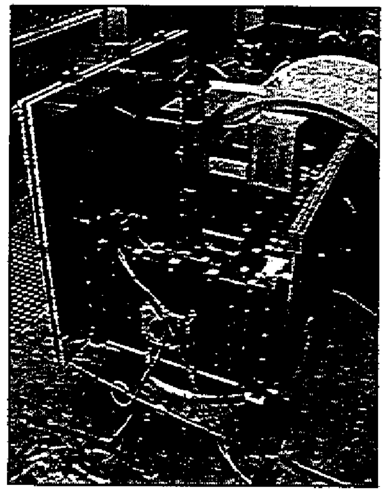
16 April 1999
Mr Pete Thomas

Mr Pete Thomas, AFRL/VSDD, 505-846-1867
Peter.J.Thomas@aero.org

Purpose/Outline

- Briefly Describe MightySat Program
- Review MightySat II.2 Payload Capability
- Discuss MightySat II.2 Manifest Process
- Identify Current II.2 Manifest Status
- Discuss II.1 and II.2 Launch Vehicle Interests

MightySat Description



GOALS:

- Demonstrate AFRL Technologies
  - Where space flight required
- Provide Affordable Adaptable Platform to Customer Base
  - AFRL Technologies
  - Orbiting "Lab-bench" to Test High Payoff Mission Hardware
- Risk Reduction
  - Accept High-Risk Payloads
  - Spaceborne Platform to Illustrate Proof-of-Concept
    - Flight Heritage
    - Component-Level Test and Demonstration
- Develop AFRL's Internal Integration Capabilities
- Provide Experience to Junior Air Force Personnel
- Further and Transition Space Science & Technology

APPROACH: Series of Mission-Neutral Smallsat Flight Experiments

- 18-24 month Launch Centers
- AFRL provides experiments
- I&T at AFRL AEF
- Launch from Shuttle or OSP
- SMC/TE RSC Conducts Ops

STATUS: *MSat I*:

- Satellite Refurbished
- 5 Experiments integrated at AEF
- Shipped to GSFC Oct '97
- NASA Phase 2/3 Review Mar '98
- HES and Can Installation May'98
- Shipped to KSC Aug '98
- Launched: STS-88 4 Dec '98
- Successfully Deployed 14 Dec '98
- Satellite and Experiments Working Perfectly!

MSat II.1:

- 8 Experiments
- Completed CDR Feb '98
- AEF I&T Started Jun '98
- 4 Payloads Integrated by Oct '98
- 3 Other Payloads I/F Tested Dec '98
- Bus Delivered to AEF 28 Feb '99
- Launch on OSP 2 Apr '00

MSat II.2:

- Began Manifest Process Nov '98
- 56 Candidate Experiments To Date
- Focus is Key Distributed Aperture Technologies

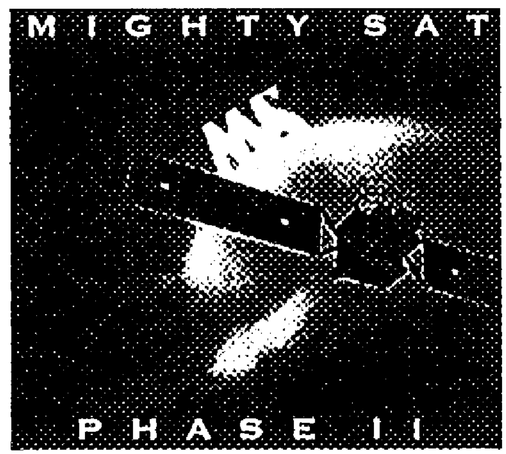
What is MightySat II.2 ?

Program Office

- 1 Civilian, 3 Military, 3 Tech Support
- Within AFRL/VSDD
- Focussed on Mission Execution
- Not scientists or technologists

AFRL Tech Demo Mission

- List of Proposed Experiment Concepts
- STW/AR hardware built for MS II mission



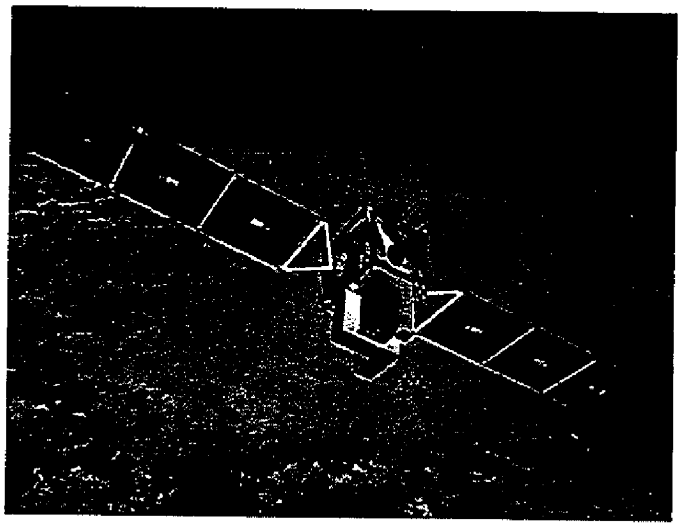
Funding Line (FY00 to FY03)

- $29M POM; $16M after AFRL taxes/overhead
  - $9.5M for Spacecraft Bus
  - $1.5M for Integration & Test
  - $2.7M for Launch and Mission Ops
  - $2.3M for program office / technical support

Spacecraft Contract

- Spectrum Astro, Gilbert AZ
- Small Spacecraft Development Effort
- MS II.1 Bus Design (starting point)
- Some Spacecraft Parts (Lot Buys)

II.2 Capabilities



Upgraded spacecraft capability will require additional program funding

Parameter	MS II.1 Capability	Upgrade Capability
Altitude	215-400 nmi	200-1000 nmi
Satellite Weight	285 lbs	400 lbs
Payload Weight	125 lbs	185 lbs
Satellite Power Gen	330 W	535 W
Payload Power Usage	70 W (avg)	200 W (avg)
External Payload Vol	20 x 24 x 18 "	40 x 24 x 24"
Pointing Knowledge	0.1 deg	0.1 deg
Pointing Control	0.2 deg	0.2 deg
Propulsion	None	TBD
Processor	RAD6000	RAD6000
Data Storage	380 Mbytes	1 GByte
Downlink Rate	1 Mbps	5 Mbps

Primary Constraints

Current Funding

$10M Bus limits spacecraft complexity / performance

$1M Launch budget limits mission orbit/ mission life

- Other launch options cost ~ $8M

$2M Operations budget limits mission complexity

Funding Profile limits schedule flexibility

Technical Constraints

- STS launch system

Ejection system limits volume / weight (400 lbs)

Orbit limited to 200-300 nmi at 51.6 deg inclination

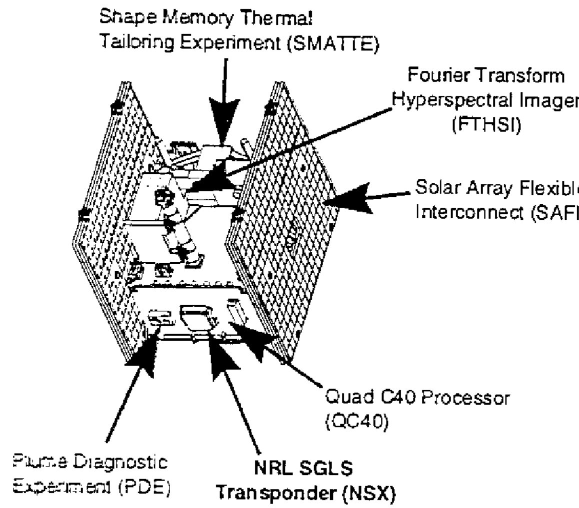
Experimenter funding could relieve this constraint

- Current Bus design is not compatible with high-radiation orbits

Spacecraft Contract

- Scope of contracted effort (small satellite)

- Number of missions: 2 firm + 3 options

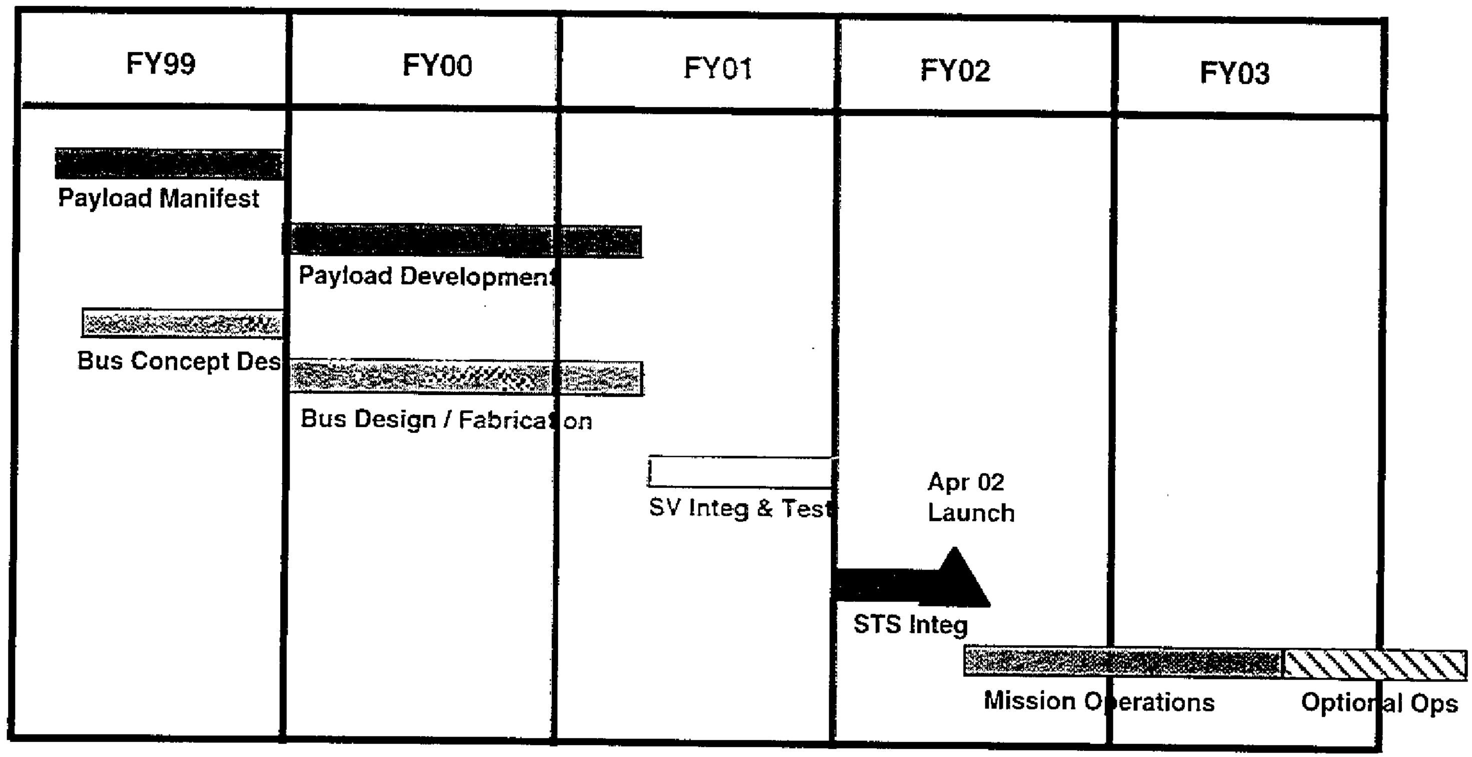


AFRL Mission

- Primary Mission is for demonstration of AFRL technologies

- Experiments require AFRL sponsorship

II.2 Mission Development

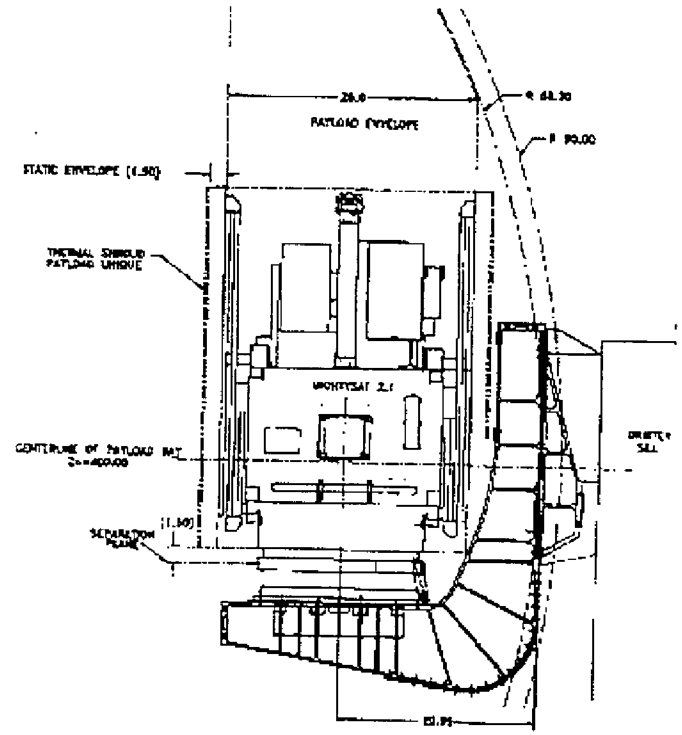


- FY99 contains no funds for contracted spacecraft development
- MightySat does not fund payload development
- Space vehicle integration & test performed at KAFB

II.2 Launch & Operations

Launch

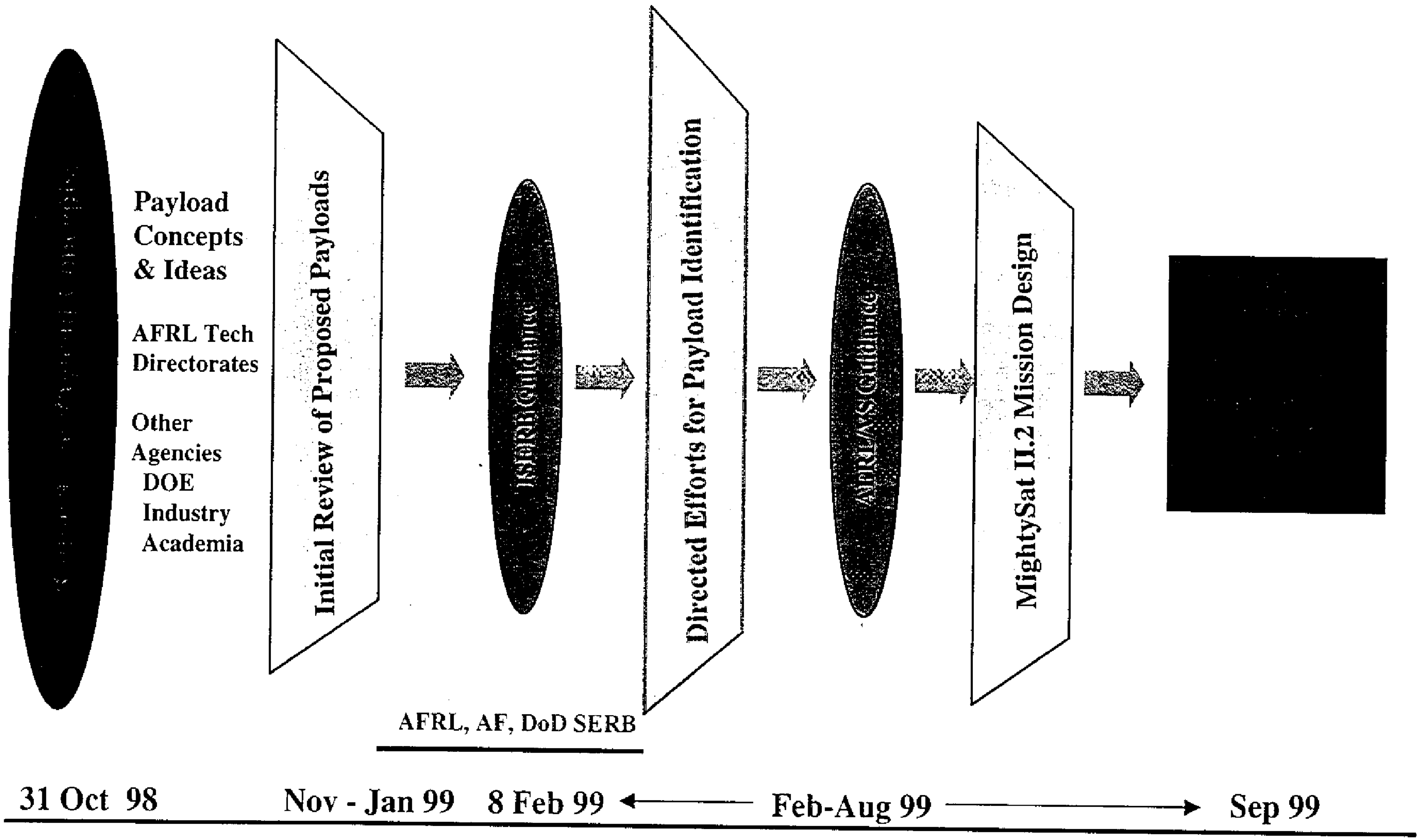
- Launch via ejection from Space Shuttle (baseline)
- But interested in higher altitude launch opportunities
- New ejection system under development by NASA
  - Accommodates moderate satellite growth from II.1
- Nominal ejection orbit: 210 nmi, 51.6 deg
- One year mission life mandates orbit-raising



Mission Operations

- Use of worldwide AFSCN ground sites
- SGLS-compatible system with 1 Mbps downlink
- Operations led by SMC/TEO
- Operations center at KAFB

II.2 Payload Manifest Process



Payload Selection Considerations

Programmatic

- AFRL Priority / AFRL Support
- Diversity of AFRL sponsorship
- Importance to User Community
- Funding availability/ potential
- Compatibility with MightySat Schedule
- Connections to External Agencies

Technical

- Need for 1-year Space Demonstration
- Compatibility with Mission Constraints
- Compatibility with available payload resources
- Synergy with other manifested payloads
- Technology Maturity
- Risk to satellite or overall mission

MightySat II.2 Manifest Status

- Received Approx 60 Candidate Experiments
- SAB - Provided Guidance
  - MightySat II.2 Very Favorably Endorsed
  - Focus of Key Distributed Aperture Technologies
- Have Held Several Discussions With NRO/AS&T
  - Coordinating Enhanced GPS Receiver Payload
- Manifest Effort Continues till Aug '98
  - TechSat 21 MSat II.2 Manifest Workshop 29-30 Apr
  - Other Possibilities Being Explored

MightySat II.1 & II.2 Launch Vehicle Interest

- II.1 Sole Payload on Schedule for OSP2 - Mar '00
  - Program Unsuccessful in Attempting to Rideshare on OSP2 or on Other Potential Launch Vehicles
  - Current STP Funding "Challenges" Exist with OSP2
  - Highly Dependent on OSP1 Success
- II.2 Baselined for Shuttle - Apr '02
  - Not Yet Manifested on STS (too early)
  - Other Launch Vehicle with Higher Altitude Preferred
    - Available Funding Extremely Limited

Summary

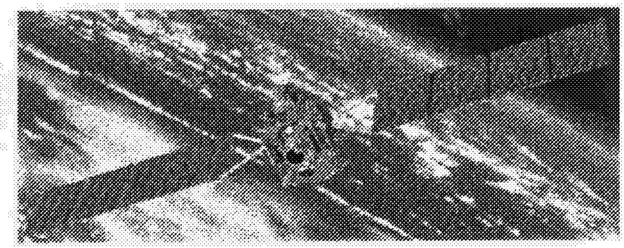
- Briefly Described MightySat Program
- Described MightySat II.2
- Provided MightySat II.2 Payload Capability
- Discussed MightySat II.2 Manifest Process
- Identified Current II.2 Manifest Status
- Discussed II.1 and II.2 Launch Vehicle Interests

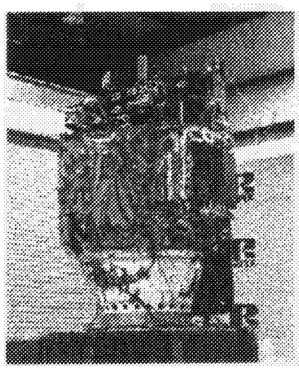
NRO RIDE SHARE CONFERENCE

15-16 APRIL 1999

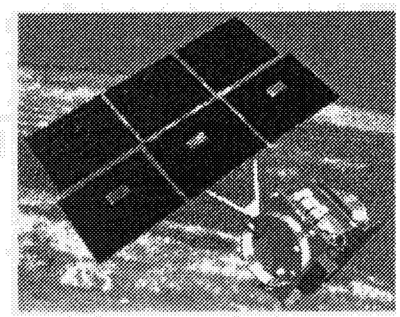
PRESENTED BY:

SCOTT YEAKEL





SPECTRUMASTRO



Spectrum Astro, Inc.
1440 N. Fiesta Blvd.
Gilbert, AZ 85233
Phone (480) 892-8200
FAX (480) 892-2949

Spectrum Astro, Inc.
3601 Aviation Blvd, Ste 3600
Manhattan Beach, CA 90266
Phone (310) 643-9303
FAX (310) 643-7583

Spectrum Astro, Inc.
2214 Rock Hill Road, Suite 101
Herndon, VA 20170
Phone (703) 742-7876
FAX (703) 742-7808

CONTENTS

- Introduction to Spectrum Astro
- Spectrum Astro Spacecraft Busses
  - SA-200S
  - SA-200B
  - SA-200HP
  - SA-200L
- Discussion Topics for “Proprietary Session”
- Spectrum Astro Points-of-Contacts

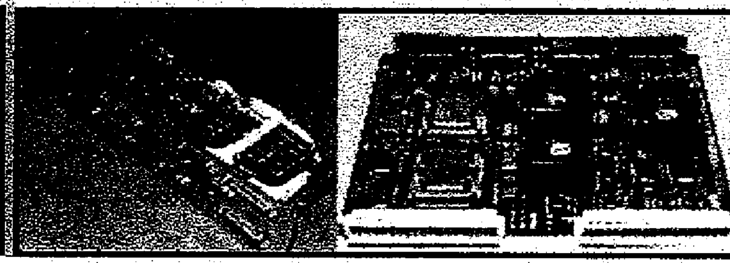
SPECTRUMASTRO

SPECTRUM ASTRO OVERVIEW

Multiple Strategies Utilized to Control and Reduce Cost

SATELLITE SYSTEMS

SPACE ELECTRONICS



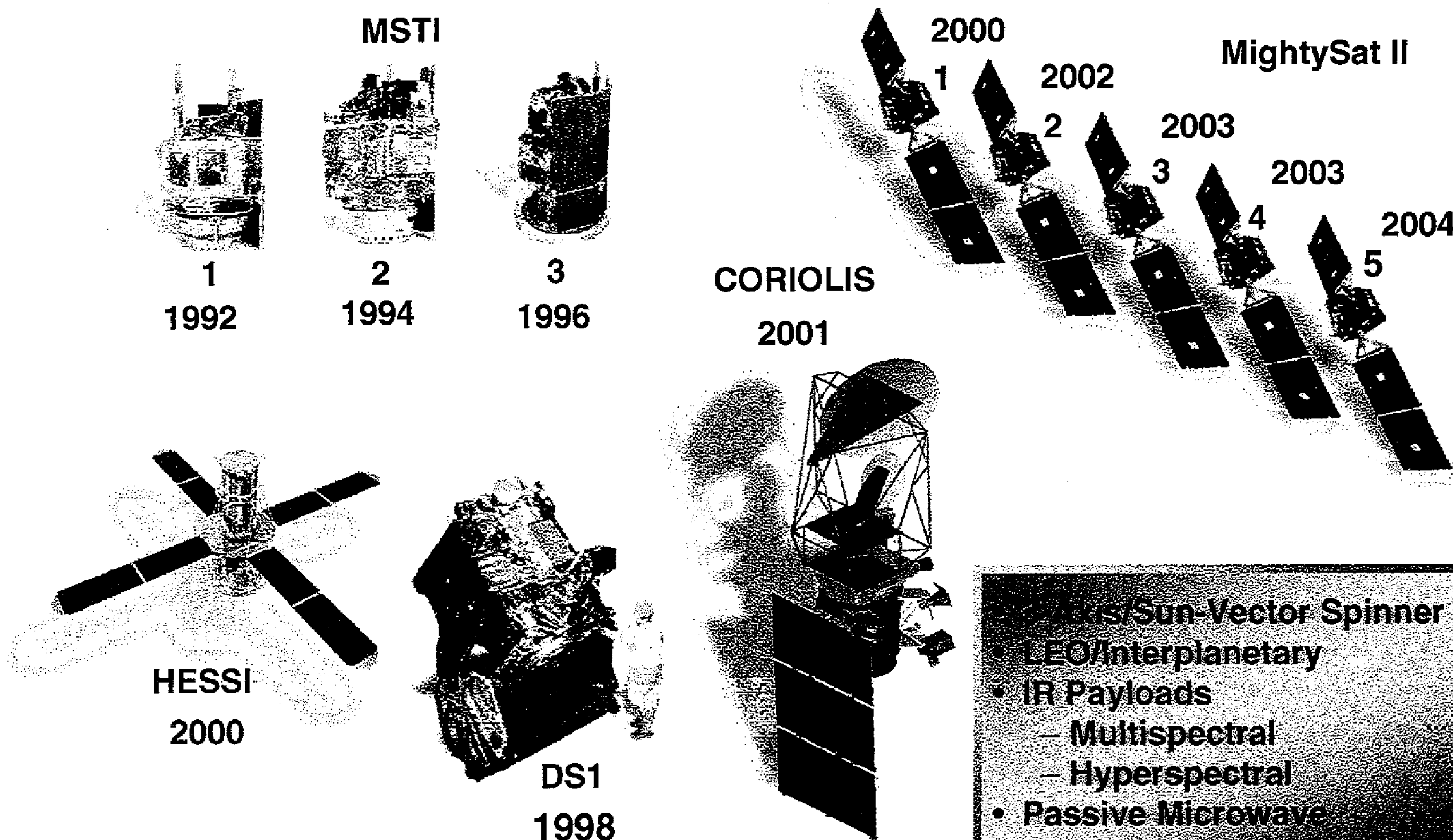
FLIGHT DATA STORAGE

- Full Service, Streamlined Space Systems Company
- Products Include Sophisticated Small to Mid-Size Satellites, Space Hardware, Ground Support, and R&D Products
- Employee Owned Business With Broad-Based Ownership
- High Productivity, Low Overhead: "Get-the-Job-Done" Culture
- 10 Yrs, 118 Successful Contracts, $140M Government Investment
- Consistent Successful Cost and Schedule Performance
- Award Winning Performance: *Inc 500*, SBA Prime Contractor-of-the-Year, Finalist Entrepreneurial Company-of-the Year, Arizona Manufacturer of the Year

GROUND SYSTEMS

DEMONSTRATION SATELLITE HERITAGE

Technology Demonstration Satellites Are Our Core Business

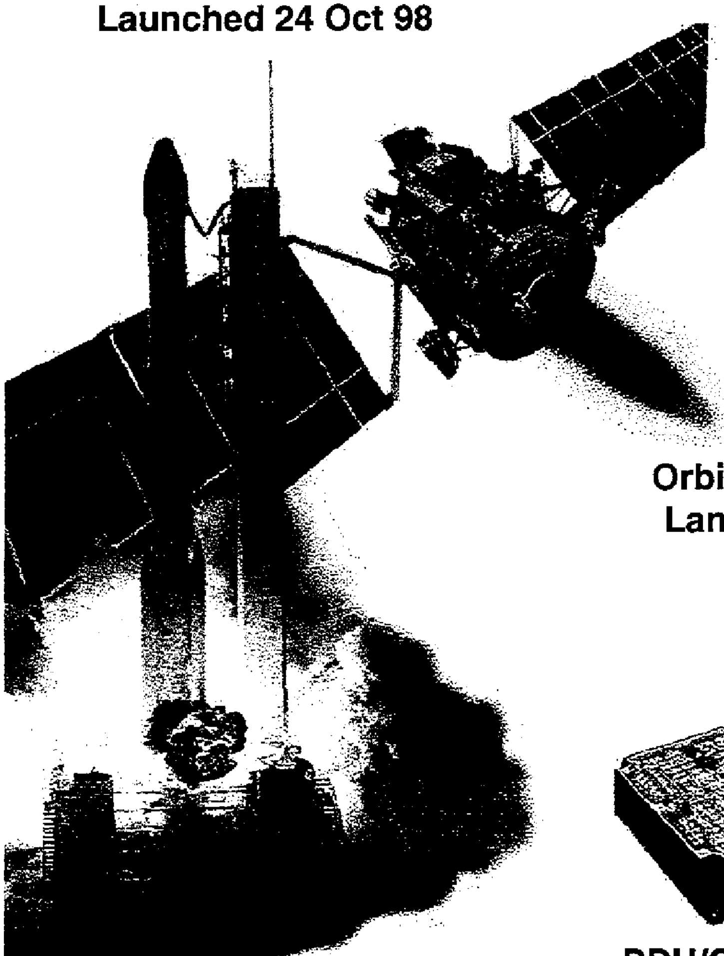


- Axis/Sun-Vector Spinner
- LEO/Interplanetary
- IR Payloads
  - Multispectral
  - Hyperspectral
- Passive Microwave

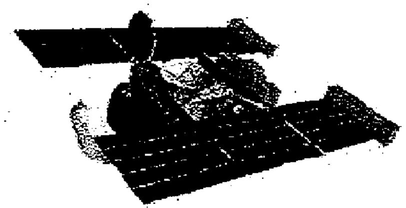
SPECTRUMASTRO

RECENT SPECTRUM ASTRO SUCCESSES

DEEP SPACE 1
Launched 24 Oct 98



STARDUST
Launched 7 Feb 99

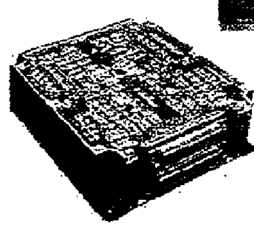


LUNAR PROSPECTOR
Launched 6 Jan 98

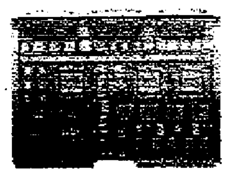
C&DH Subsystem

MARS 98
Orbiter Launched 11 Dec 98
Lander Launched 3 Jan 99

UL/DL

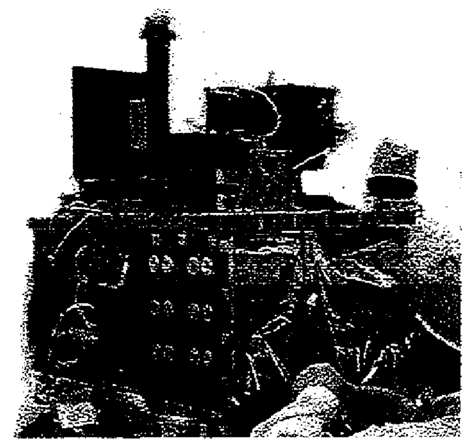


PDU/CCU



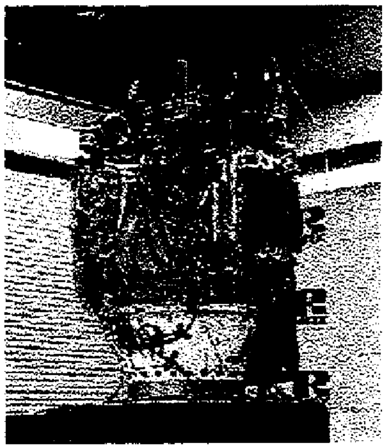
P/L ACE I/F

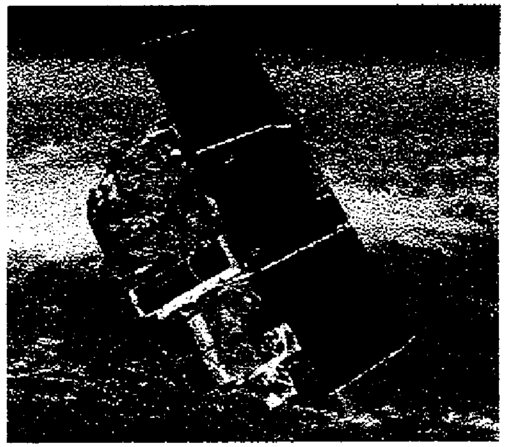
MIGHTYSAT
Integration Oct 98 - Mar 99



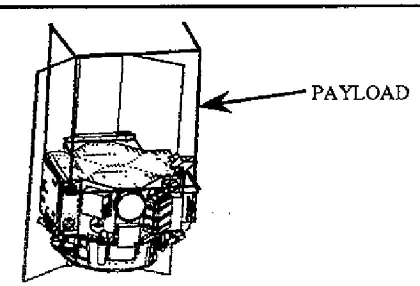
SPECTRUMASTRO

SA-200S SPACE VEHICLE



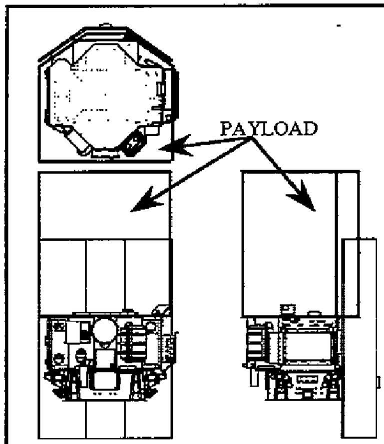


Spacecraft Configuration



Payload Volume = 1.0 x 1.2 (base) x 1.3 m (Pegasus)
1.2 x 1.4 (base) x 2.4 m (Athena)

Three-View Configuration

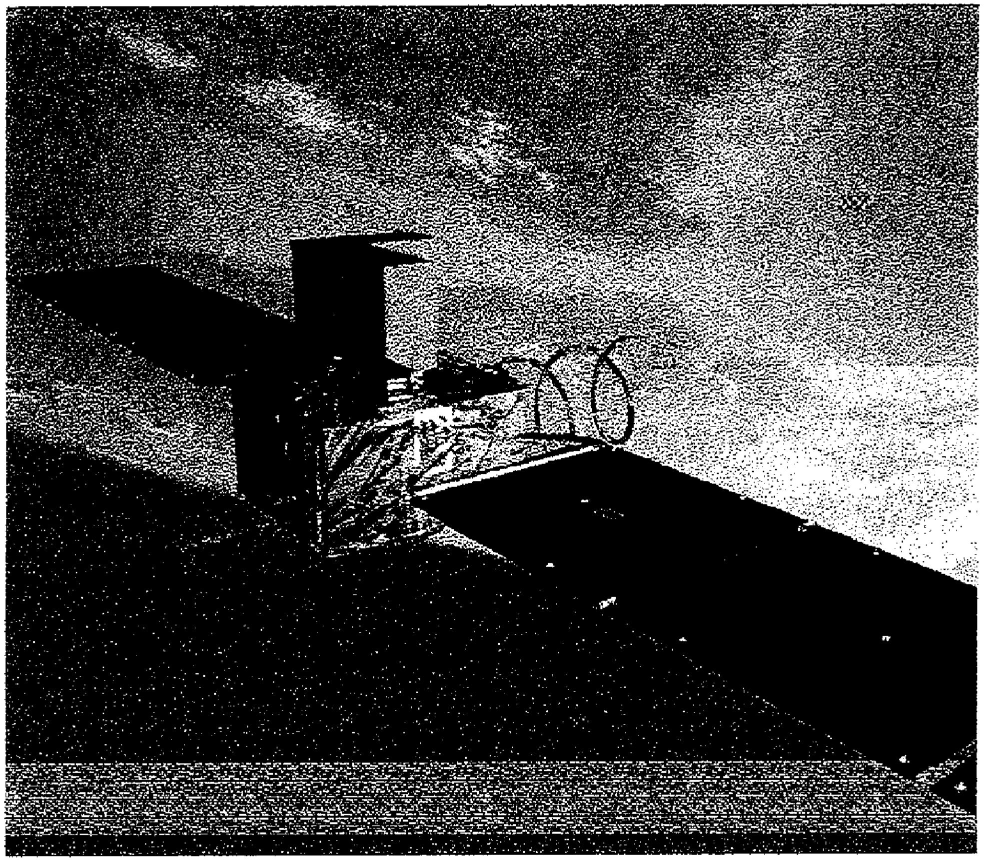


Spacecraft Capability

	SA-200S
Mission & Program	
Launch Mass	200 - 300 kg
Sunlit Array Power (BOL)	150-300 Watts (body mounted)
Launch Vehicle	Pegasus, Taurus, Athena
Mission/Orbit	Any: LEO, MEO, HEO, GEO, Planetary (stellar ACS)
Lifetime	1 - 3 Years
Mission Effectiveness	> 0.80
Redundancy Architecture	Single String w/ Selected & Functional Redundancy
Parts Program	883B / JAN TXV Upscreened B Space Materials
Product Assurance	Tailored 9858/NHB 5300.4 (1D-2)
Payload Accommodations	
Payload Mass	Up to 200 kg
Payload Power, Avg/Peak	60/180 W
Payload Field of View	2π Steradian
Payload Data Handling	Up to 25 Mbps
Payload Data Storage	64 Gbit
Data Downlink Rate	1-10 Mbps
Guidance & Control	
Attitude Control	3-Axis, Zero Momentum
Pointing Control	$\pm$ 20 Arcsec (1σ)
Pointing Knowledge (RMS)	$\pm$ 1 Arcsec (1σ)
Pointing Modes	sun, nadir, off-set, point track, inertial
Pointing Stability	< .01°/sec
Orbit Knowledge	±100 m GPS
Orbit/Trajectory Control	<± 0.5 km, 25 kg-N_2H_4
Momentum Management	RCS
Command and Data Handling	
Ground Control I/F	S-Band (X-Band Available)
Data Interface	STDN/DSN
S/C & Payload Telemetry	≤2 Mbps
Commands	Up to 2 Kbps

SPECTRUMASTRO

SA-200B SPACE VEHICLE AND MIGHTYSAT II DESCRIPTION

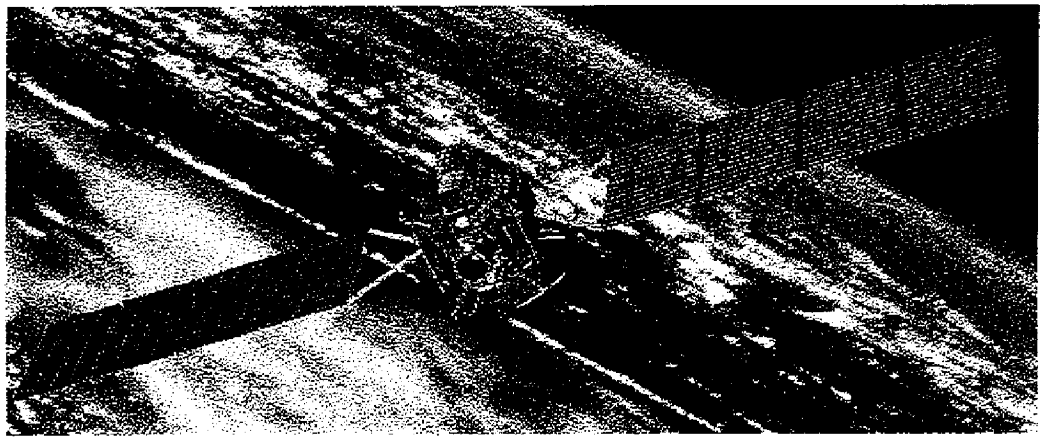


Payload Accommodations

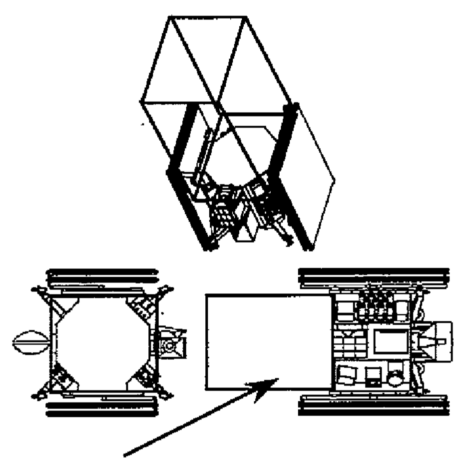
	Nominal	Available
Mission & Program		
Launch Mass	125 kg	200 kg
Sunlit Array Power	310 Watts	400 Watts
Launch Vehicle	STS Hitchhiker, ALV Secondary, MSLS, Med Lite	
Mission/Orbit	All: LEO, MEO, HEO, GEO (Stellar ACS)	
Lifetime	1 Year	3 Years
Mission Effectiveness	>0.8	>0.9
Redundancy Architecture	Single String w/ Selected & Functional Redundancy	
Parts Program	883B / JAN TXV Space Mat'ls	Class-S, MSFC-527, MIL-975
Product Assurance	Tailored 9858/NHB 5300.4 (1D-2)	
Payload Accommodations		
Payload Mass	60 kg	**100 kg**
Payload Power - Avg / Peak	75 / 150 W	125 / 250 W
Payload Vol (base, base, ht)	0.5 x 0.5 x 0.6 m	
Payload Field of View	2π Steradian	$>2\pi$ Steradian
Payload Data Handling	20 MBps	20 x n MBps
Payload Data Storage	160 MByte	1.2 GByte
Data Downlink Rate	256 Kbps	5 Mbps
Onboard Data Processing	.5 MIP	16 MIP
Guidance & Control		
Attitude Control	3-Axis, Zero Momentum	Pitch Bias, Spin
Pointing Control	<0.23°	<0.1°
Pointing Knowledge (RMS)	<0.15°	<0.05°
Pointing Stability	< 0.1°/sec	< .01°/sec
Orbit Knowledge	±1 Km Gnd Eph.	± 100 m (GPS)
Orbit Control	PPT	N_2, N_2H_4
Momentum Management	Magnetic	RCS
Command and Data Handling		
Ground Control I/F	UHF	Secure SGLS/STDN
S/C & Payload Telemetry	32 Kbps	256 Kbps
Commands	2 Kbps	32 Kbps

SPECTRUMASTRO

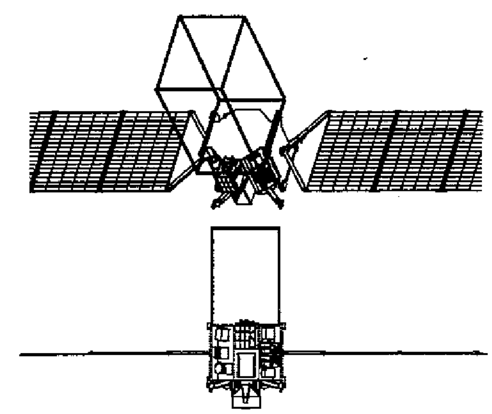
SA-200HP SPACE VEHICLE



Stowed Configuration



Deployed Configuration

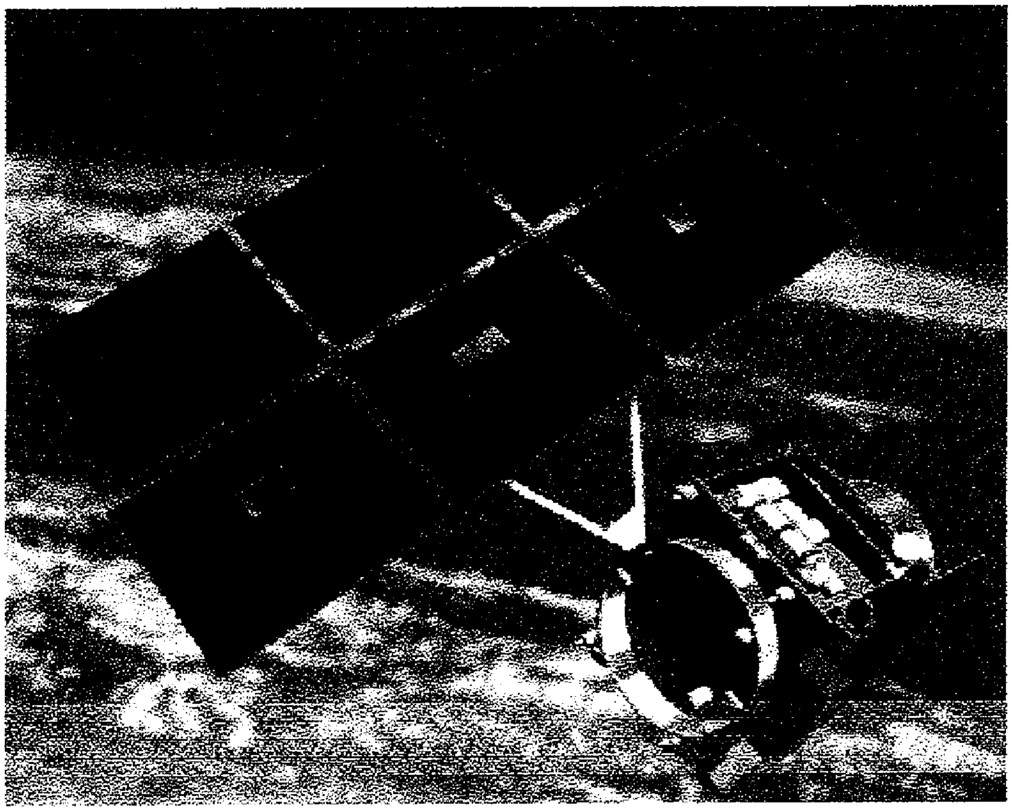


Spacecraft Capability

	SA-200HP
Mission & Program	
Launch Mass	300 - 500 kg
Sunlit Array Power (BOL)	800 - 3,000 Watts
Launch Vehicle	Delta II, Taurus, Athena
Mission/Orbit	Any. LEO, MEO, HEO, GEO, Planetary (stellar ACS)
Lifetime	3-5 years
Mission Effectiveness	>.85 - >.95
Redundancy Architecture	Single String w/ Selected & Functional Redundancy
Parts Program	883B / JAN TXV Upscreened B Space Materials
Product Assurance	Tailored 9858/NHB 5300.4 (1D-2)
Payload Accommodations	
Payload Mass	Up to 300 kg
Payload Power, Avg/Peak	800 / 1,800 W
Payload Field of View	2π Steradian
Payload Data Handling	> 24 Mbps
Payload Data Storage	160 Mbyte to 60 Gbit
Data Downlink Rate	1-10 Mbps
Guidance & Control	
Attitude Control	3-Axis, Zero Momentum
Pointing Control	± 20 Arcsec (1σ)
Pointing Knowledge (RMS)	± 1 Arcsec (1σ)
Pointing Modes	sun, nadir, off-set, point track, inertial
Pointing Stability	< .01°/sec
Orbit Knowledge	± 5 cm Radial (Differential GPS)
Orbit/Trajectory Control	<±0.5 km, 22-50 kg-N2H4
Momentum Management	Magnetic & RCS
Command and Data Handling	
Ground Control I/F	S-Band, X-Band Down
Data Interface	STDN/DSN
S/C & Payload Telemetry	≤8 Mbps
Commands	Up to 2 Kbps

SPECTRUMASTRO

SA-200LL SPACE VEHICLE



Spacecraft Capability

	SA-200LL
Mission & Program	
Launch Mass	450 - 840 kg
Sunlit Array Power (BOL)	1,200-1,500 Watts
Launch Vehicle	Delta II, Taurus, Athena
Mission/Orbit	Any: LEO, MEO, HEO, GEO, Planetary (stellar ACS)
Lifetime	>5 years
Mission Effectiveness	>0.85 - >0.95
Redundancy Architecture	Full Redundancy
Parts Program	883B / JAN TXV Upscreened B Space Materials
Product Assurance	Tailored 9858/NHB 5300.4 (1D-2)
Payload Accommodations	
Payload Mass	Up to 500 kg
Payload Power, Avg/Peak	300 / 1000 W
Payload Field of View	> 2π Steradian
Payload Data Handling	500 Mbits
Payload Data Storage	160 Mbyte to 60 Gbit
Data Downlink Rate	1-20 Mbps
Guidance & Control	
Attitude Control	3-Axis, Zero Momentum
Pointing Control	± 20 Arcsec (1σ)
Pointing Knowledge (RMS)	± 1 Arcsec (1σ)
Pointing Modes	sun, nadir, off-set, point track, inertial
Pointing Stability	< .01°/sec
Orbit Knowledge	± 5 cm Radial (Differential GPS)
Orbit/Trajectory Control	<±0.5 km, 16 kg-N2H4
Momentum Management	Magnetic & RCS
Command and Data Handling	
Ground Control I/F	S-Band, X-Band Down
Data Interface	STDN/DSN
S/C & Payload Telemetry	≤8 Mbps
Commands	Up to 2 Kbps

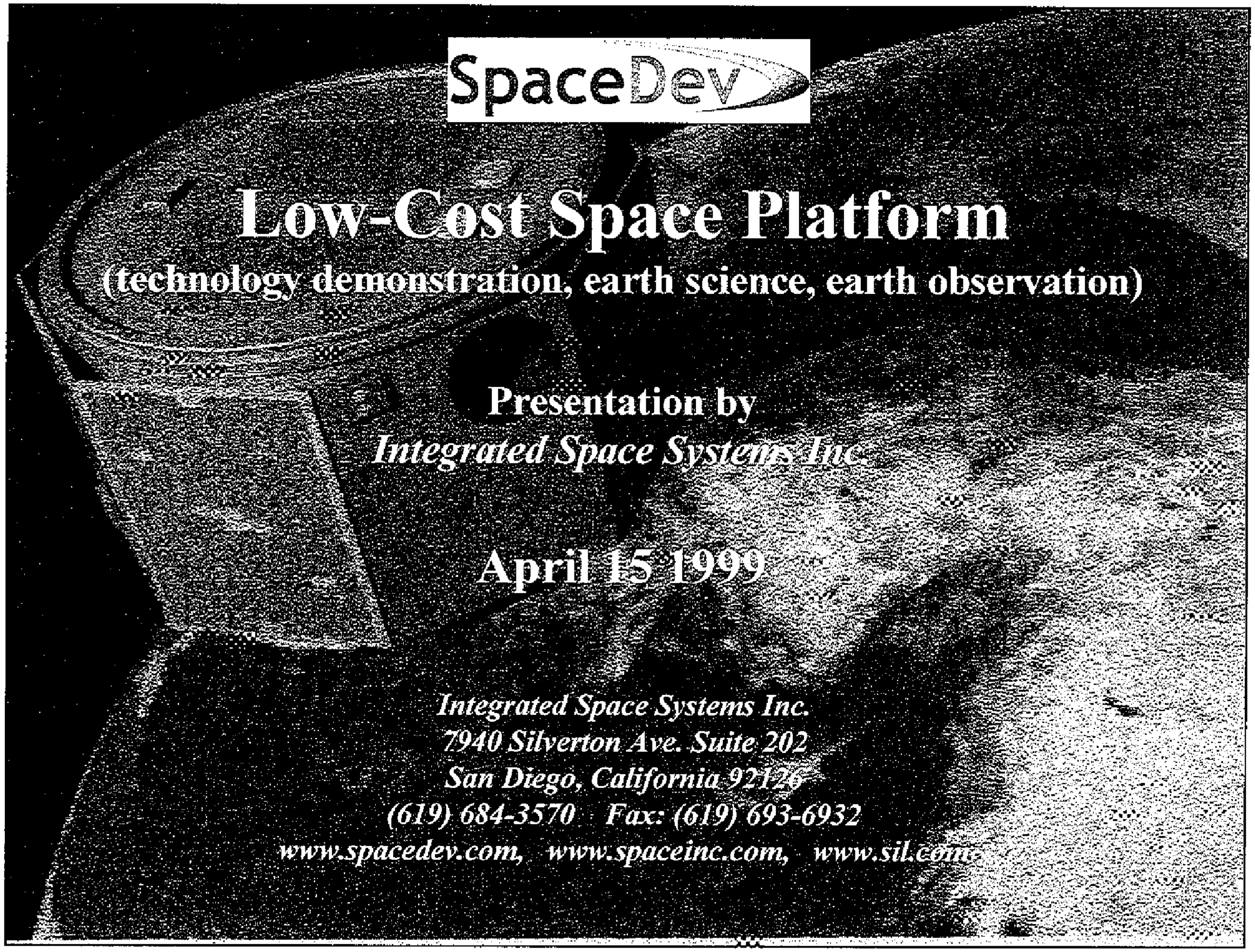
SPECTRUMASTRO

SPECTRUM ASTRO POINTS-OF-CONTACT

- Howard Parks, Director of Marketing
  (480) 692-8200
  howard.parks@specastro.com

- Dom Conte, East Coast Office Manager
  (703) 742-7876
  dom.conte@dchub.specastro.com

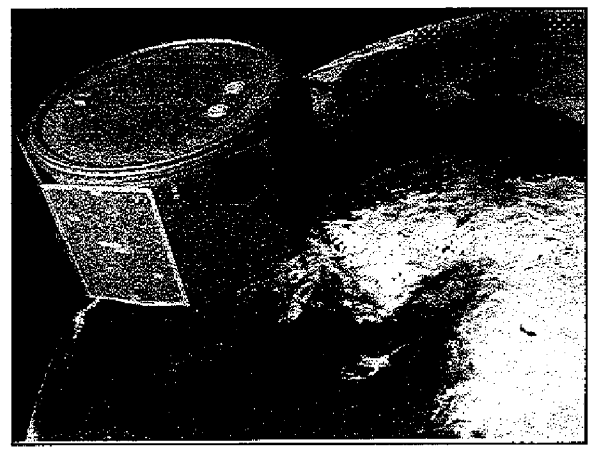
- Scott Yeakel, Director of Military Programs
  (480) 692-8200
  scott.yeakel@specastro.com


SpaceDev
Low-Cost Space Platform
(technology demonstration, earth science, earth observation)
Presentation by
Integrated Space Systems Inc
April 15 1999
Integrated Space Systems Inc.
7940 Silverton Ave. Suite 202
San Diego, California 92126
(619) 684-3570 Fax: (619) 693-6932
www.spacedev.com, www.spaceinc.com, www.sil.com

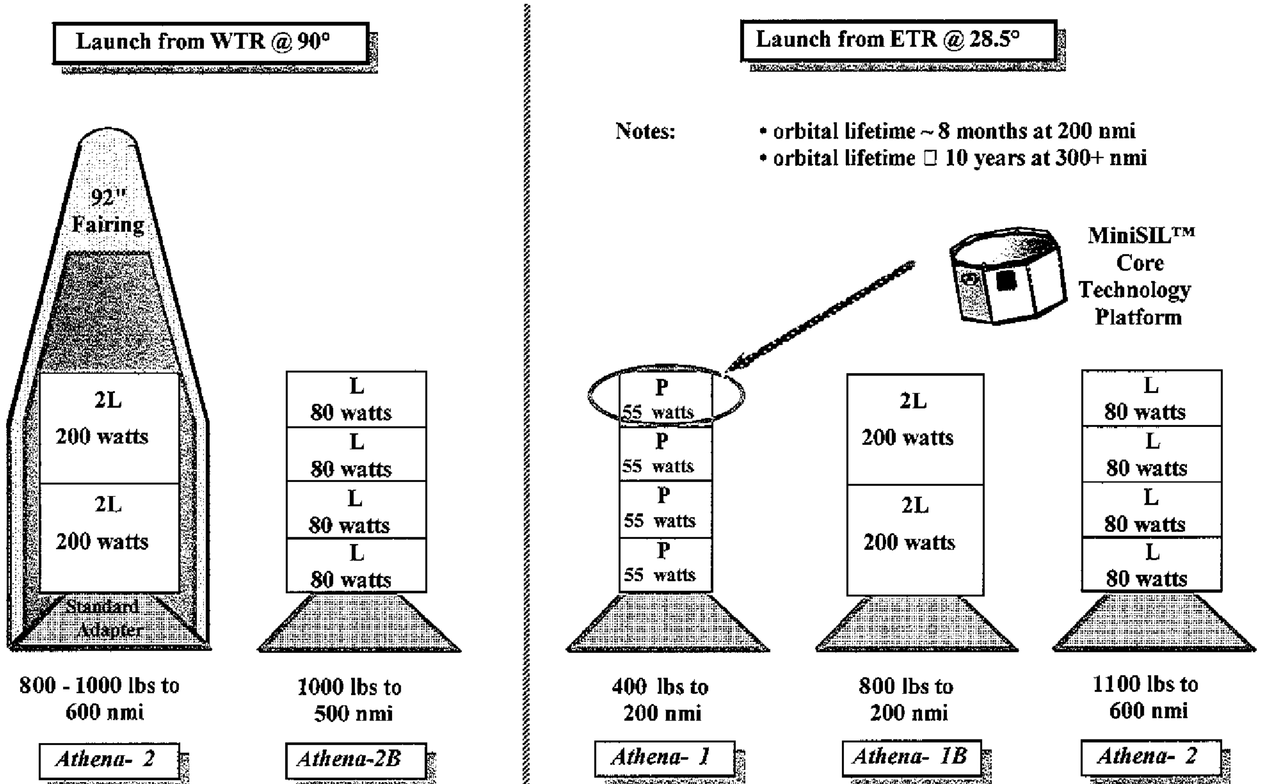
Mission

Combine low-cost, versatile small satellites together with a low cost launch system to provide the customer with consistent, rapid access to space.

- Provide a standardized experiment platform
    - Maximum experiment flexibility
    - 1, 2, 3 or 4 stacked spacecraft
    - For a Total of 400 to 800 lbs of payload
    - matching to the customer's mission
- Launched on a low cost domestic launch vehicle
    - target access to space
    - target high radiation dose
    - target sun-synchronous
    - target special pointing requirements
- For the lowest possible cost per mission
    - For a single, all inclusive price,
    - Empowering the technology (payload) owner
    - With the least risk



Custom Solutions - Athena Example (multiple configurations)



10/23/98

Competition Sensitive

Custom Solutions - Commercial Price List

6 Payloads per MiniSIL™ Shared Ride Options

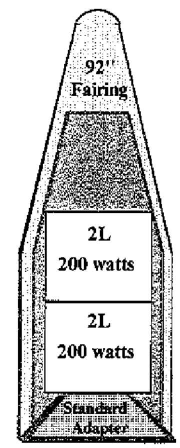
Each MiniSIL provides 6 payload slots (total of 12 tickets)
5% discount for each additional slot used by the same payload

Includes: Project management, mission integration , spacecraft, payload integration and test, launch vehicle, launch campaign and range costs

Unpriced Options: Mission operations, ground systems, launch vehicle insurance, payload insurance

Mission	Orbit		Payload Parameters		
	Inclin. deg	Altitude km	Weight kg	Volume M3	Cost Each $M
Access to Space - short life	28.5	185	25	0.07	$ 4.15M
Access to Space - 5 year	28.5	600	25	0.07	$ 4.45M
High inclined	50.0	600	25	0.07	$ 4.45M
Sun Synchronous	SSO	600	25	0.07	$ 4.95M

25 kg = 55 lbs, 0.07 M^3 = 4,300 in^3



Competition Sensitive

Custom Solutions - Commercial Price List

4 Payloads per MiniSIL™ Shared Ride Options

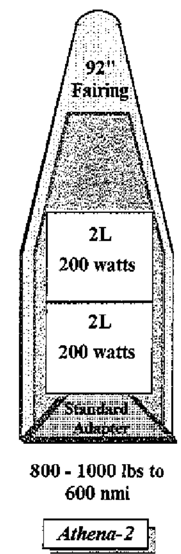
Each MiniSIL provides 4 payload slots (total of 8 tickets)
5% discount for each additional slot used by the same payload

Includes: Project management, mission integration , spacecraft, payload integration and test, launch vehicle, launch campaign and range costs

Unpriced Options: Mission operations, ground systems, launch vehicle insurance, payload insurance

Mission	Orbit		Payload Parameters		
	Inclin. deg	Altitude km	Weight kg	Volume M3	Cost Each $M
Access to Space - short life	28.5	185	35	0.1	$ 6.25M
Access to Space - 5 year	28.5	600	35	0.1	$ 6.65M
High inclined	50.0	600	35	0.1	$ 6.65M
Sun Synchronous	SSO	600	35	0.1	$ 7.35M

35 kg = 77 lbs, 0.1 M^3 = 6,100 in^3



Competition Sensitive

Custom Solutions - Commercial Price List

1 Payload per MiniSIL™ Individual Spacecraft Option

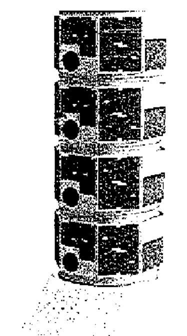
Each MiniSIL sold individually (total of 4 gold tickets)

Includes: Project management, mission integration , spacecraft, payload integration and test, launch vehicle, launch campaign and range costs

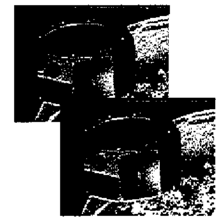
Unpriced Options: Mission operations, ground systems, launch vehicle insurance, payload insurance

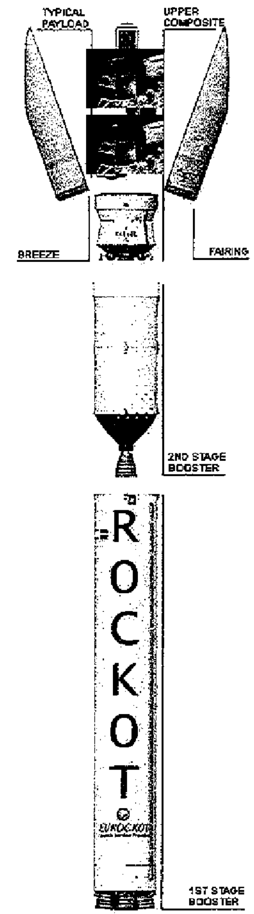
Mission	Orbit		Payload Parameters		
	Inclin. deg	Altitude km	Weight kg	Volume M3	Cost Each $M
Access to Space - short life	28.5	185	55	0.2	$ 17.25M
Access to Space - 5 year	28.5	600	55	0.2	$ 17.25M
High inclined	50.0	600	55	0.2	$ 17.25M
Sun Synchronous	SSO	600	55	0.2	$ 19.45M

55 kg = 120 lbs, 0.20 M^3 = 12,200 in^3



Custom Solutions - Commercial Price List





6 Payloads per MiniSIL™ Shared Ride Options

Each MiniSIL provides 6 payload slots (total of 12 tickets)
5% discount for each additional slot used by the same payload

Includes: Project management, mission integration , spacecraft, payload integration and test, launch vehicle, launch campaign and range costs

Unpriced Options: Mission operations, ground systems, launch vehicle insurance, payload insurance

Mission	Orbit		Payload Parameters		
	Inclin. deg	Altitude km	Weight kg	Volume M3	Cost Each $M
Access to Space	28.5	185	25	0.07	$ 3.55M

25 kg = 55 lbs, 0.07 M^3 = 4,300 in^3

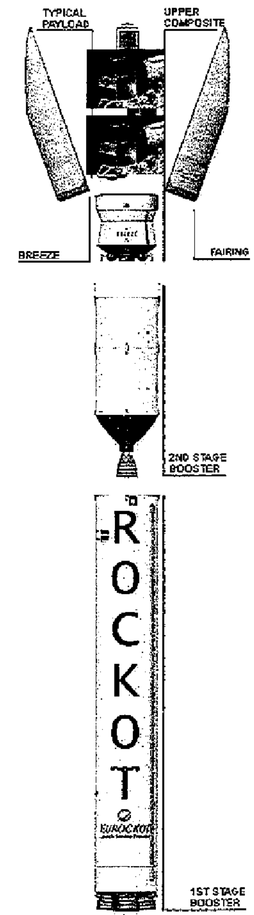
Custom Solutions - Commercial Price List

4 Payloads per MiniSIL™ Shared Ride Options

Each MiniSIL provides 4 payload slots (total of 8 tickets)
5% discount for each additional slot used by the same payload

Includes: Project management, mission integration , spacecraft, payload integration and test, launch vehicle, launch campaign and range costs

Unpriced Options: Mission operations, ground systems, launch vehicle insurance, payload insurance



Mission	Orbit		Payload Parameters		
	Inclin. deg	Altitude km	Weight kg	Volume M3	Cost Each $M
Access to Space	28.5	185	35	0.1	$ 5.35M

35 kg = 77 lbs, 0.1 M^3 = 6,100 in^3

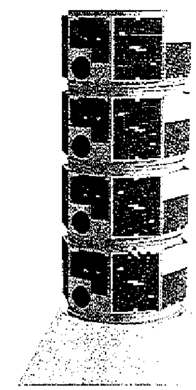
Program Status - Fulfilling the Mission

Our U.S. team has been formed and a low cost path to space has been found.

- Integration Contractor - Integrated Space Systems Inc. (SpaceDev)
- Spacecraft Contractor - Space Innovations Ltd. (SpaceDev)
- Launch Services Contractor - Lockheed Martin Astronautics

- Providing service directly to the payload owner
  - Slots (tickets) on multi-user spacecraft
  - Whole spacecraft on multi-spacecraft launch

- Utilize MiniSIL™ stacked spacecraft capability
  - Fully manifest a small launch vehicle launch
  - Sell payload rides and/or whole spacecraft in stack
  - Maintain consistent payload and launch vehicle interfaces
  - Develop and maintain a regular launch schedule for each mission type



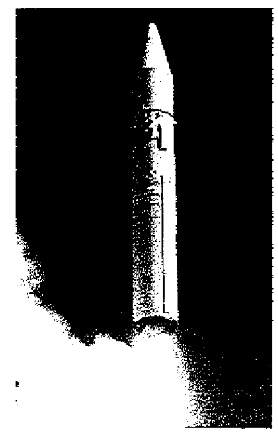
- We are ready to take reservations

Custom Solutions - One Potential Path to Launch

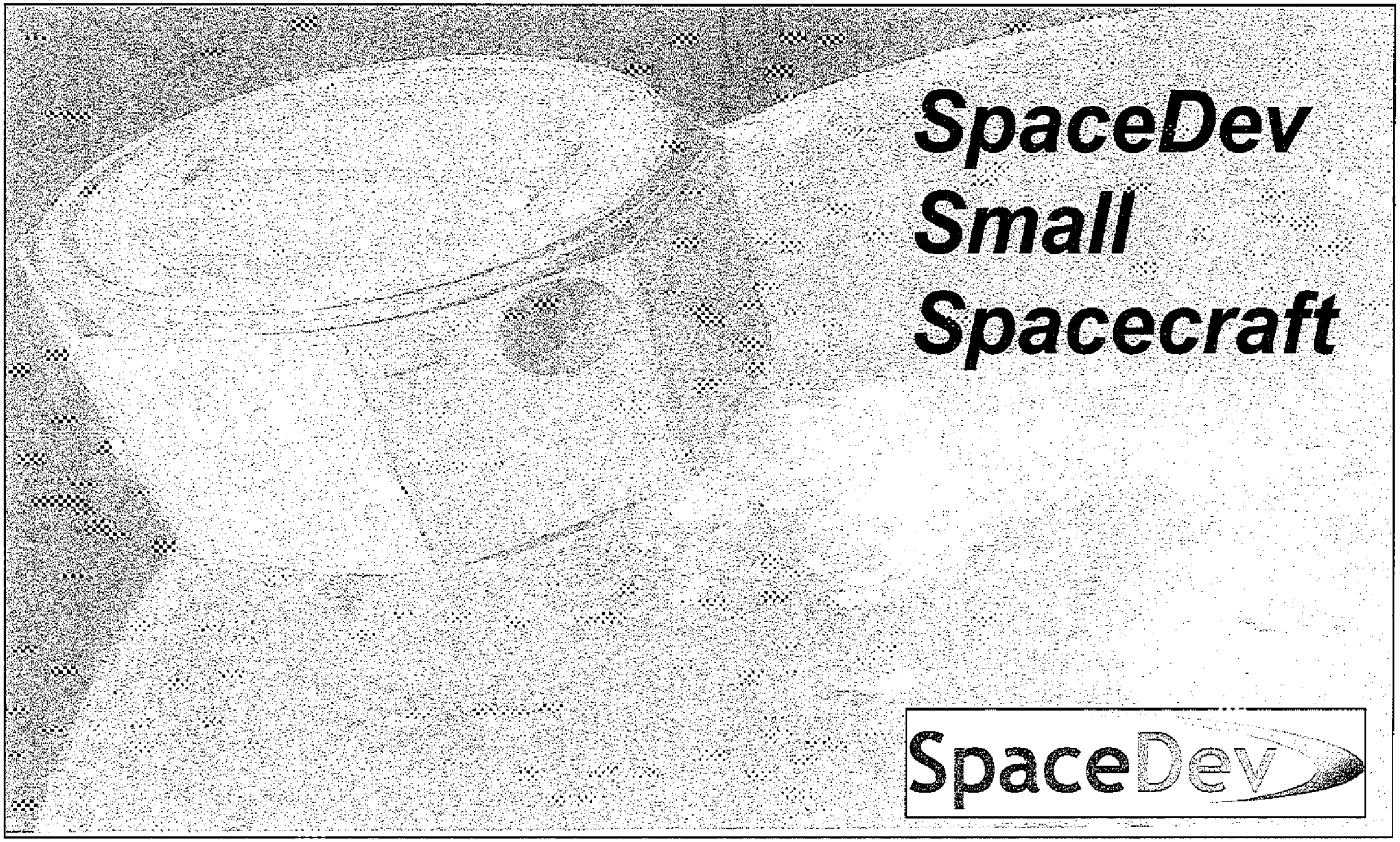
1) FASTMAX Study
   Determine feasibility of multi-mission launch.
   Customer evaluation of ISS/SIL capabilities.

2) Contract to deliver spacecraft for launch.

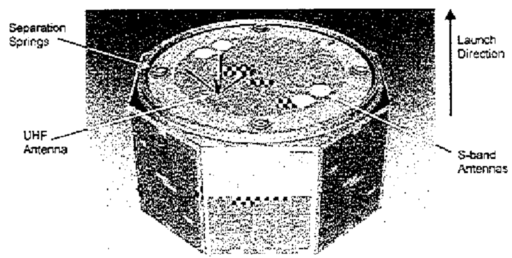
Program Management	ISS
Integration Contractor	ISS
LSIC	ISS
Mission Design	ISS
Spacecraft Subsystems	SIL
Spacecraft Bus	SIL
Spacecraft Final IA&T	ISS
Launch Vehicle	LMA
Launch Support	LMA/ISS
Ground Systems Provider	optional
Mission Operations	optional

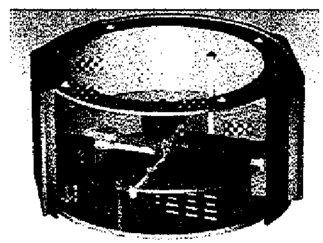


3) Initial Launch Capability - *ATP + 24 months*


SpaceDev
Small
Spacecraft
SpaceDev

MiniSIL™ Spacecraft Model Specific Features



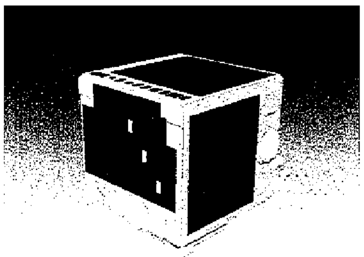


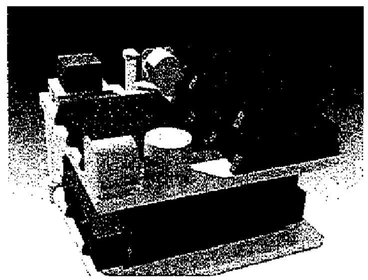
MiniSIL-P shown.
MiniSIL-L and MiniSIL-2L mount subsystem equipment outside of thrust cylinder which allows all of thrust cylinder inner diameter to be used by payload(s).

Model	Octagon Outside Diameter (in)	Spacecraft Height (in)	Spacecraft Total Weight (lb)	Payload Weight (lb)	Payload Volume		Payload Power (sunlit)	Data Rate* for Circular Orbit (Mbps)		
					Dia. (in)	Height (in)		200 nmi	400 nmi	600 nmi
MiniSIL-P	43	25	220-330 lb	90-130 lb	36	12	up to 55W	3.8	1.5	1.0
MiniSIL-2P	43	50	330-440 lb	130-180 lb	36	35	up to 135W	3.8	1.5	1.0
MiniSIL-L	63	25	330-550 lb	140-270 lb	36	24	up to 80W	3.8	1.5	1.0
MiniSIL-2L	63	50	440-770 lb	200-400 lb	36	47	up to 200W	3.8	1.5	1.0

** Assumes*
1) SIL low-cost S-Band ground station (2.4 meter dish) with Convolutional and Reed-Solomon encoding
2) SIL 5 watt S-band transmitter (2.25 GHz)
3) 5 deg minimum elevation angle and 6 dB link margin

MicroSIL™ Spacecraft Model Specific Features



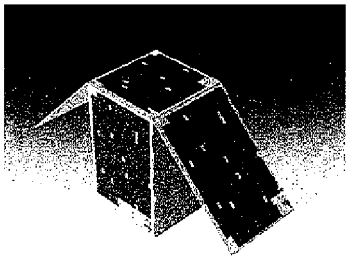


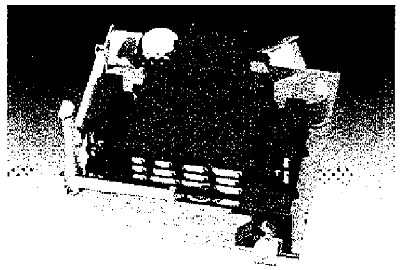
Payload are mounted on payload shelf separated from spacecraft subsystems.
S = Standard
3 = 3 axis stabilized
G = Gravity gradient torque

Model	Cube Outside Dimensions (in)	Spacecraft Height (in)	Spacecraft Total Weight (lb)	Payload Weight (lb)	Payload Volume		Payload Power (sunlit)	Data Rate* for Circular Orbit (Mbps)		
					Shelf. (in)	Height (in)		200 nmi	400 nmi	600 nmi
MicroSIL-S	19.3x19.3	20.1	100-145 lb	40-65 lb	18.5x18.5	6.7	30W	2.4	1.0	0.6
MicroSIL-3	19.3x19.3	20.1	100-145 lb	30-55 lb	18.5x18.5	6.7	25W	2.4	1.0	0.6
MicroSIL G	19.3x19.3	20.1	100-145 lb	25-50 lb	18.5x18.5	6.7	30W	2.4	1.0	0.6

** Assumes*
1) SIL low-cost S-Band ground station (2.4 meter dish) with Convolutional and Reed-Solomon block encoding
2) SIL 2 watt S-band transmitter (2.25 GHz)
3) 5 deg minimum elevation angle and 6 dB link margin

Extended MicroSIL™ Spacecraft Model Specific Features





Payload are mounted on payload shelf separated from spacecraft subsystems.
LS = Large, spin stabilized
L3 = Large, 3 axis stabilized
XS = Extended, spin stabilized
X3 = Extended, 3-axis stabilized

Model	Cube Outside Dimensions (in)	Spacecraft Height (in)	Spacecraft Total Weight (lb)	Payload Weight (lb)	Payload Volume		Payload Power	Data Rate* for Circular Orbit (S-Band / X-Band Mbps)		
					Shelf. (in)	Height (in)	(sunlit)	200 nmi	400 nmi	600 nmi
MicroSIL-LS	23.5x23.5	24	120-180 lb	60-90 lb	22.5x22.5	10.5	50W	2.4 / 22.0	1.0 / 5.8	0.6 / 2.7
MicroSIL-L3	23.5x23.5	24	120-180 lb	50-80 lb	22.5x22.5	10.5	45W	2.4 / 22.0	1.0 / 5.8	0.6 / 2.7
MicroSIL-XS	23.5x23.5	31.5	155-220 lb	80-110 lb	22.5x22.5	18.5	75W	2.4 / 22.0	1.0 / 5.8	0.6 / 2.7
MicroSIL-X3	23.5x23.5	31.5	155-220 lb	70-100 lb	22.5x22.5	18.5	70W	2.4 / 22.0	1.0 / 5.8	0.6 / 2.7

** Assumes*
1) SIL low-cost S/X ground station (2.4 meter dish) with Convolutional and Reed-Solomon encoding
2) SIL 2-watt S-band transmitter (2.2 GHz) and SIL 3-watt X-band transmitter (8.4 GHz)
3) Ground station antenna 5 ° and 40° minimum elevation angle at S-Band and X-Band respectively, with 6 dB link margin

NanoSAT Spacecraft Model Specific Features

Simple, small spacecraft designed for one year on-orbit lifetime and quick launch as a secondary ride opportunity.

- **Spacecraft design weight < 25 lbs**
- **Passive thermal control**
- **Functional life 1 year**
- **Small arrays and rechargeable batteries**

Model	Cube Outside Dimensions (in)	Spacecraft Height (in)	Spacecraft Total Weight (lb)	Payload Weight (lb)	Payload Volume		Payload Power (sunlit)	Data Rate* for Circular Orbit (Mbps)		
					Shelf. (in)	Height (in)		200 nmi	400 nmi	600 nmi
NanoSAT	10"	12"	25 lb	5 lbs	10.0x10.0	1.5	10 watts	2.4	1.0	0.6

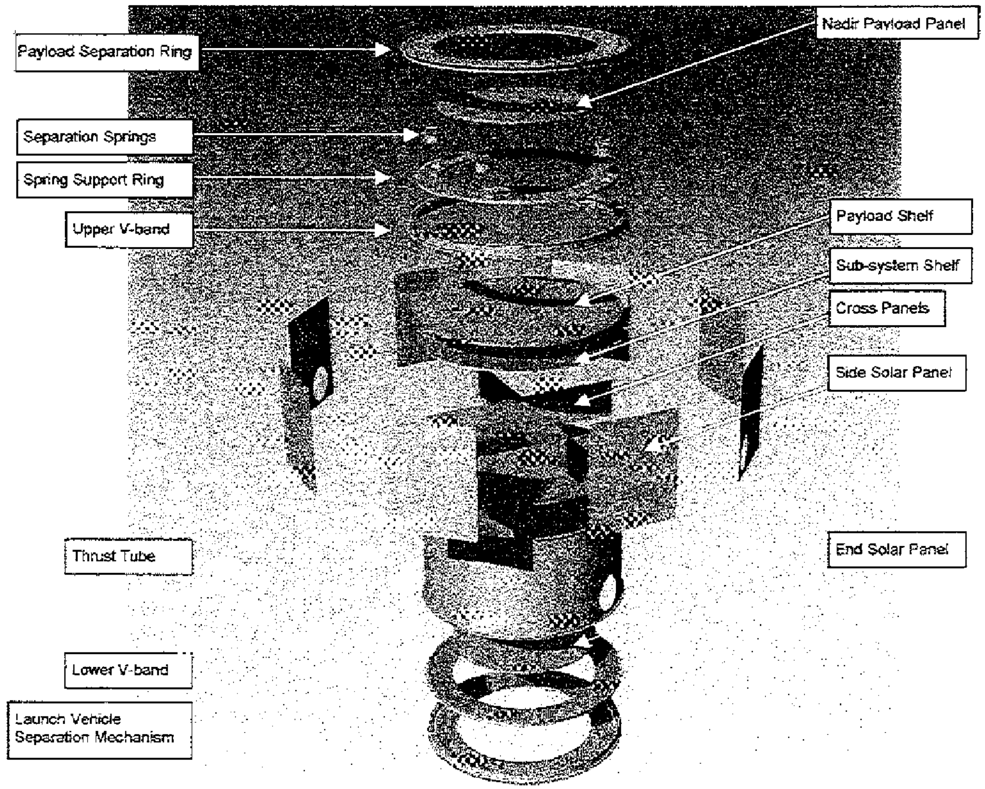
* *Assumes*

1) SIL low-cost S/X ground station (2.4 meter dish) with Convolutional and Reed-Solomon encoding
2) SIL 2-watt S-band transmitter (2.2 GHz) and SIL 3-watt X-band transmitter (8.4 GHz)
3) Ground station antenna 5° and 40° minimum elevation angle at S-Band and X-Band respectively, with 6 dB link margin

SIL Subsystems and Component Heritage

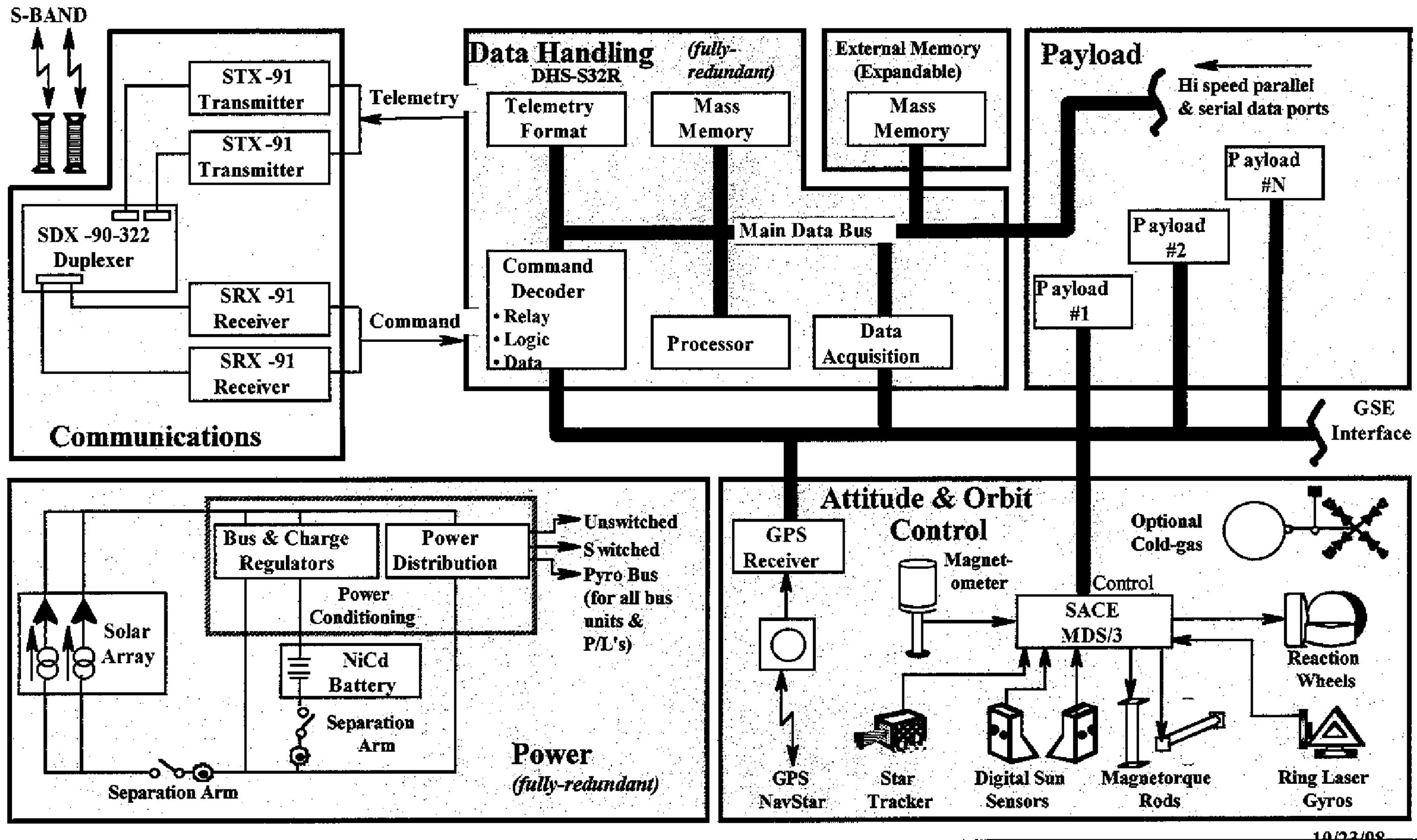
- Australia's FedSat: MicroSIL Satellite
- Danish ÖRSTED satellite (for CRI): S-band transceivers
- Pakistan BADR-B satellite (for SUPARCO): S-band transmitters, receivers, diplexer; on-board computer and software; power conditioning system, NiCd batteries; digital sun sensors, magnetometer; magnetorquer rods, attitude control system; ground station equipment
- Argentinian SAC-C small satellite (for CONAE): 1W S-band transceivers, 5W S-band transmitter, 3W X-band transmitter
- ESA PROBA small satellite (for Verhaert, Belgium): S-band equipment; SPARC-based on-board SIL computer; power system, batteries; S-band ground station
- UK STRV-1a/b small satellites (for DRA): S-band equipment; sun and Earth sensors; attitude control system. Designed and manufactured the attitude sensors, Fan-beam Attitude Sensor Electronics (FASE) Spacecraft Attitude Control Electronics (SACE), S-Band Receiver and Diplexer, and Charge Detector Experiment (CDE).
- French and German small satellites (for CNES and DASA): S-band patch antennas
- Solar and Heliospheric Observatory (SOHO): Design and Development of the Command and Data Handling System (CDHS) for the Coronal Diagnostic Spectrometer (CDS) instrument . Development of the optimum detector interfaces, triple redundant transputer-based processing architecture and memory elements.
- ERS-2 PCSUs, Envisat DEU and PCSUs: Manufactured the Power Conditioning and Supply Unit (PCSU) for ERS-2, completed manufacture of the PCSU and Digital Electronics Units (DEU) for the next generation Environment remote sensing satellite (ENVISAT).
- Spectrum-X JET-X Attitude Sensor PSU: Designed and manufactured the Jet-X Attitude Sensor Power Supply Unit for the Russian Spectrum-X satellite. The power supply unit provides the regulated power to the Jet-X attitude sensor electronics including CCDs.
- DRS (for ESTEC): Designed and manufactured the Data Relay System (DRS) spread spectrum modem for ESTEC.
- Meteosat-3 Experiment: Developed an experiment for the Meteosat-3 satellite launched in 1988 to monitor radiation at the experiment site and perform radiation effects monitoring of a TMS320 processor and various memory chips.

MiniSIL™ Spacecraft Structural Detail



Competition Sensitive

MiniSIL™ Spacecraft Component Schematic



Competition Sensitive

Competition Sensitive

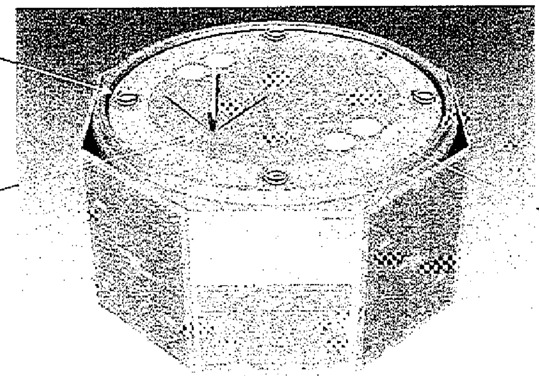
Point Design Example

SpaceDev

Point Design Example

<u>Spacecraft Instrumentation and Capabilities</u>

Multi Spectral Imager



15 meter resolution at 800 km
75 km swath
1000 sq.km. stored on board at full resolution

Store and Forward Data

VHF/UHF
Payload modem 38.4 K bits per second

Available Payload

22 lb (10.0 kg) of payload used
72 lb (32.8 kg) of payload mass available
16 watts used by primary experiments
15 watts margin depending on orbit selected

Point Design Example

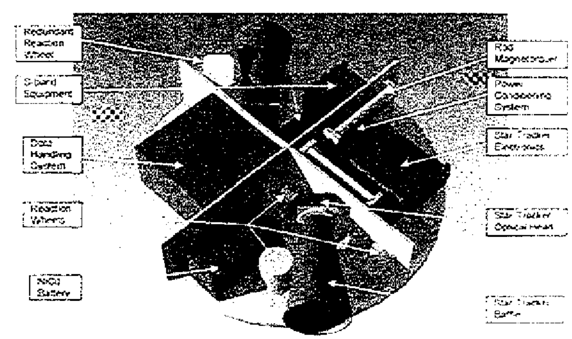
Attitude Control - Mode: 3 axis stabilized

Pointing accuracy

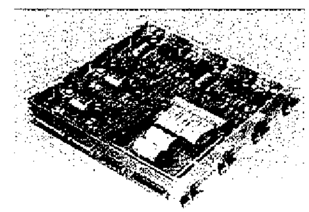
Pointing	Roll	Pitch	Yaw
Knowledge	15 arc-sec	15 arc-sec	20 arc-sec
Accuracy	0.10°	0.10°	0.15°
Rates	16.5 (arc-sec)/sec	16.5 (arc-sec)/sec	33.0 (arc-sec)/sec

Sensors / Actuators

- 2 Star-tracker sensors diametrically mounted
- Global positioning system
- Reaction (momentum) wheels
- 2 digital sun sensors (SIL cots)
- magnetometer (SIL cots)
- magnetorquers (SIL cots)

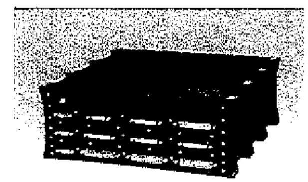


Point Design Example



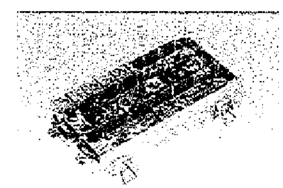
Power System

Solar Cells	Gallium Arsenide
Batteries	Nickel cadmium rechargeable
Power conditioner	Fully redundant 28 volts (SIL cots)



Communication

Spacecraft	S-Band (NASA / ESA standard) 1 M bit per second (SIL cots) @ 400 nmi
Imager	X-Band (encrypted) (S-band used as backup) 16 M bit per second @ 400 nmi



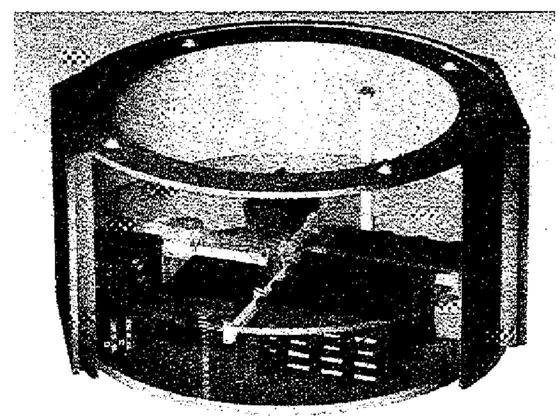
Point Design Example

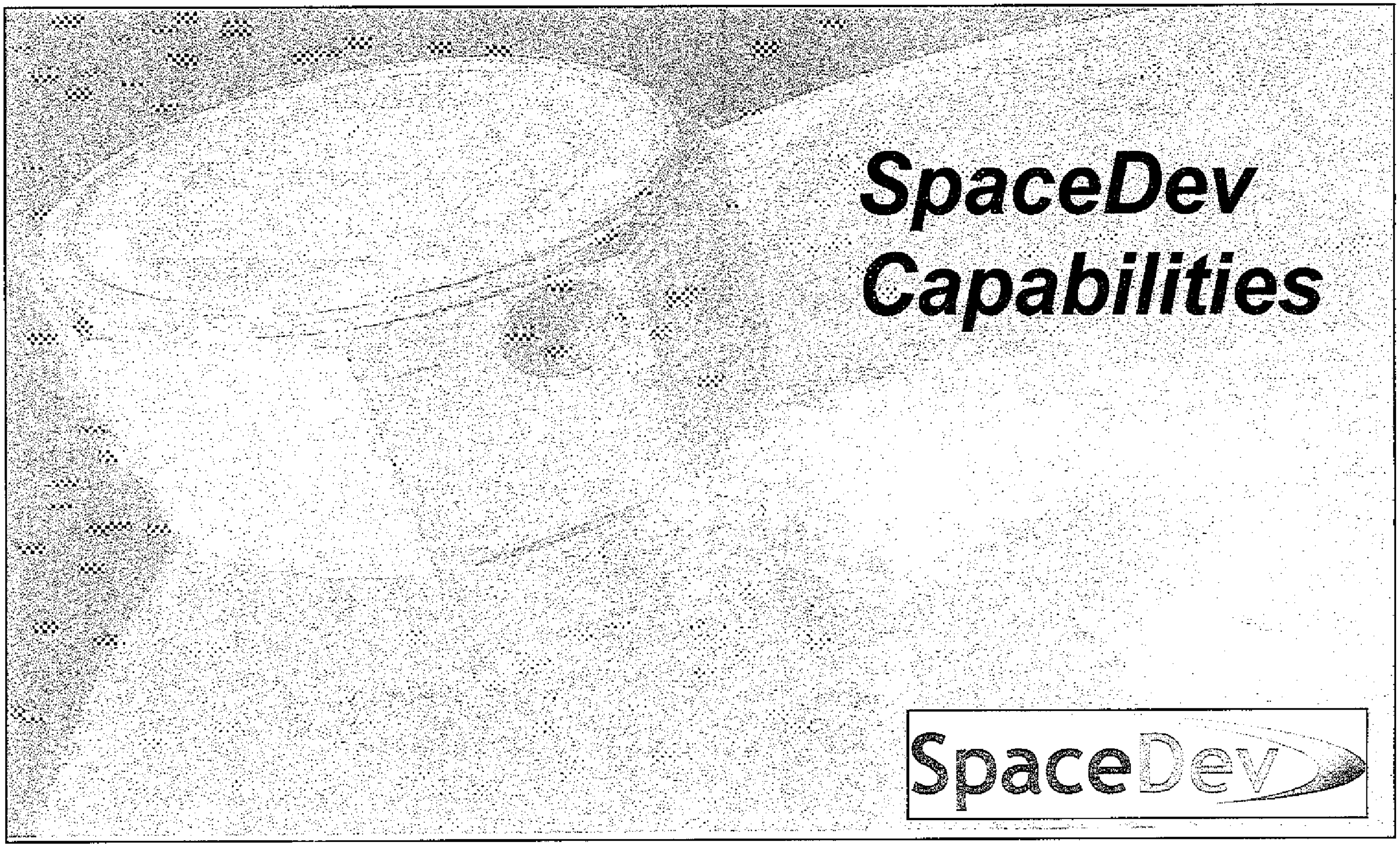
Other Systems

Structure	Aluminum structure and skin - honeycomb design
Thermal	Passive thermal blankets
Data Handling System	Rad Hard - SPARC 32 bit processor (SIL cots)
Standardized Sep System	Compatible to other MiniSILs, LVs and SVs

Payload Volume

Cylindrical space
920 mm diameter x 300 mm depth




SpaceDev
Capabilities
SpaceDev

Points of Contact

Integrated Space Systems Inc.

Jack A. Rubidoux
JackR@spaceinc.com

Phone: (619) 684-3570
Fax: (619) 693-6932
7940 Silverton Ave. Suite 202
San Diego, California 92126
United States
www.spaceinc.com

Space Innovations Ltd.

A. Kim Ward
Ward@sil.com

Phone: 044-07000-772234
Fax: 044-1635-38785
The Paddock, Hambridge Road
Newbury, Berkshire,
England RG145TQ
www.sil.com

International Business Office

Sue Rippeth
Sue.Rippeth@spacedev.com

Phone: 001-703-841-2100
Fax: 001-703-841-0669
1515 Wilson Blvd. Suite 700
Arlington, Virginia 22209
United States
www.spacedev.com

Corporate Business Development

James Benson
President and CEO
Jim@spacedev.com

7940 Silverton Ave. Suite 202
San Diego, California 92126
www.spacedev.com

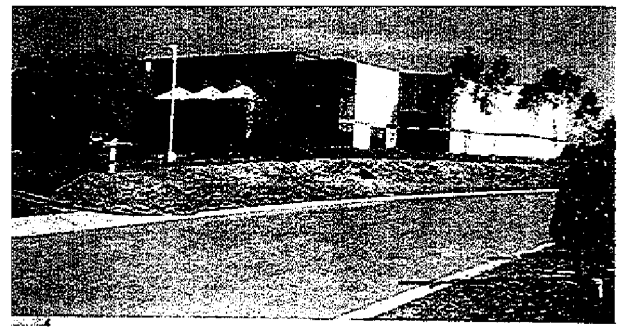
Philip Smith
Chief Operating Officer
PhilS@spacedev.com

Phone: (619) 684-3570
Fax: (619) 693-6932

ISS and SIL Capabilities & Assets

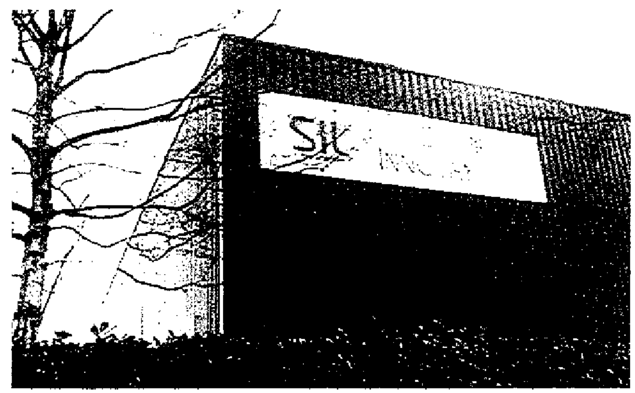
Integrated Space Systems Inc.
San Diego, California

- Program Management
- Launch Services Integration Contractor
- Mission Design
- Spacecraft Final Assembly
- Launch Support

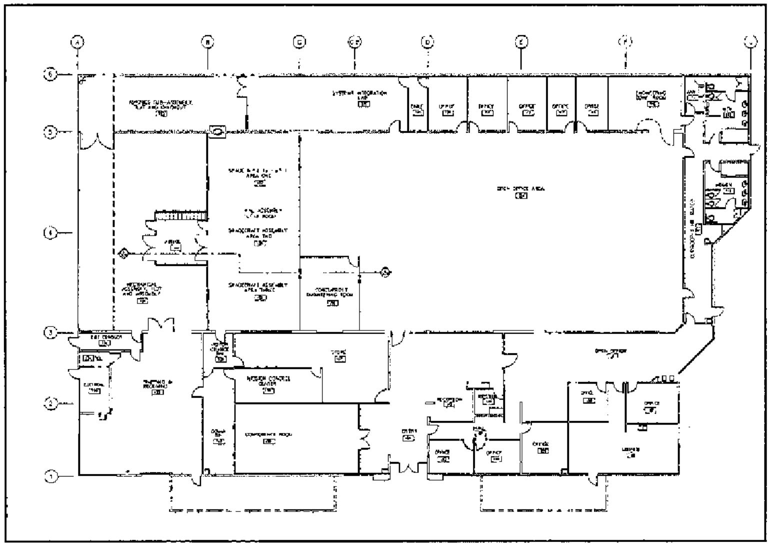


Space Innovations Ltd.
Newbury, England

- Spacecraft Bus
- Spacecraft Subsystems
- Ground Systems



Spacecraft Design, Assembly and Test Building - San Diego, California



1800 sq.ft.	Class 100,000 spacecraft assembly clean room
2500 sq.ft.	mechanical sub-assembly test and checkout area
1000 sq.ft.	avionics sub-assembly test and checkout area
680 sq.ft.	systems integration lab
860 sq.ft.	concurrent engineering lab
1750 sq.ft.	shipping and receiving area
840 sq.ft.	corporate conference room
320 sq.ft.	engineering conference room
300 sq.ft.	mission control center
7700 sq.ft.	engineering space
1350 sq.ft.	offices

Total = 25,600 sq.ft. including services

Spacecraft Key Personnel

Jan King – V.P. Space Engineering (30 plus years)

- Schriever Chair Professor (endowed chair),
  Dept. of Astronautics, United States Air Force Academy
- Vice President, Technology, Qualcomm, Inc., Boulder, Colorado
- Vice President, Boulder Operations, Orbital Sciences Corporation
- Vice President for Space Technology, Member BOD and Founder, Skylink Corporation
- Aerospace Technologist, NASA/GSFC
- Vice President for Engineering, Member of the BOD, Co-founder of the Radio Amateur Satellite Corp., Washington, D.C.

Rex Ridenoure – Chief Mission Architect (20 plus years)

- Manager, Microcosm's Space Systems Division
- Program Architect, NASA's New Millennium Program
- Project and Mission Engineer on five projects, JPL
- Mission Planner for the Voyager-2 Neptune Encounter
- Mission Engineer on GEO comsats at Hughes and Hubble at Lockheed

Spacecraft Key Personnel

Len Culhane - Chairman of the Board, Space Innovations Ltd.

Professor Len Culhane was awarded the BSc (lst Hons.) in Physics and the MSc in Physics from University College Dublin. His PhD was awarded in Space Physics by University College London. His research expertise is in X-ray astronomy, solar physics, X-ray spectroscopy, X-ray detectors and space cryogenic systems. He has won Principal Investigator roles on NASA, ESA and Japanese scientific space missions for which he has developed novel instruments for spectroscopy in the X-ray, Extreme UV and Infra-red wavelength ranges. Some of his many accomplishments include:

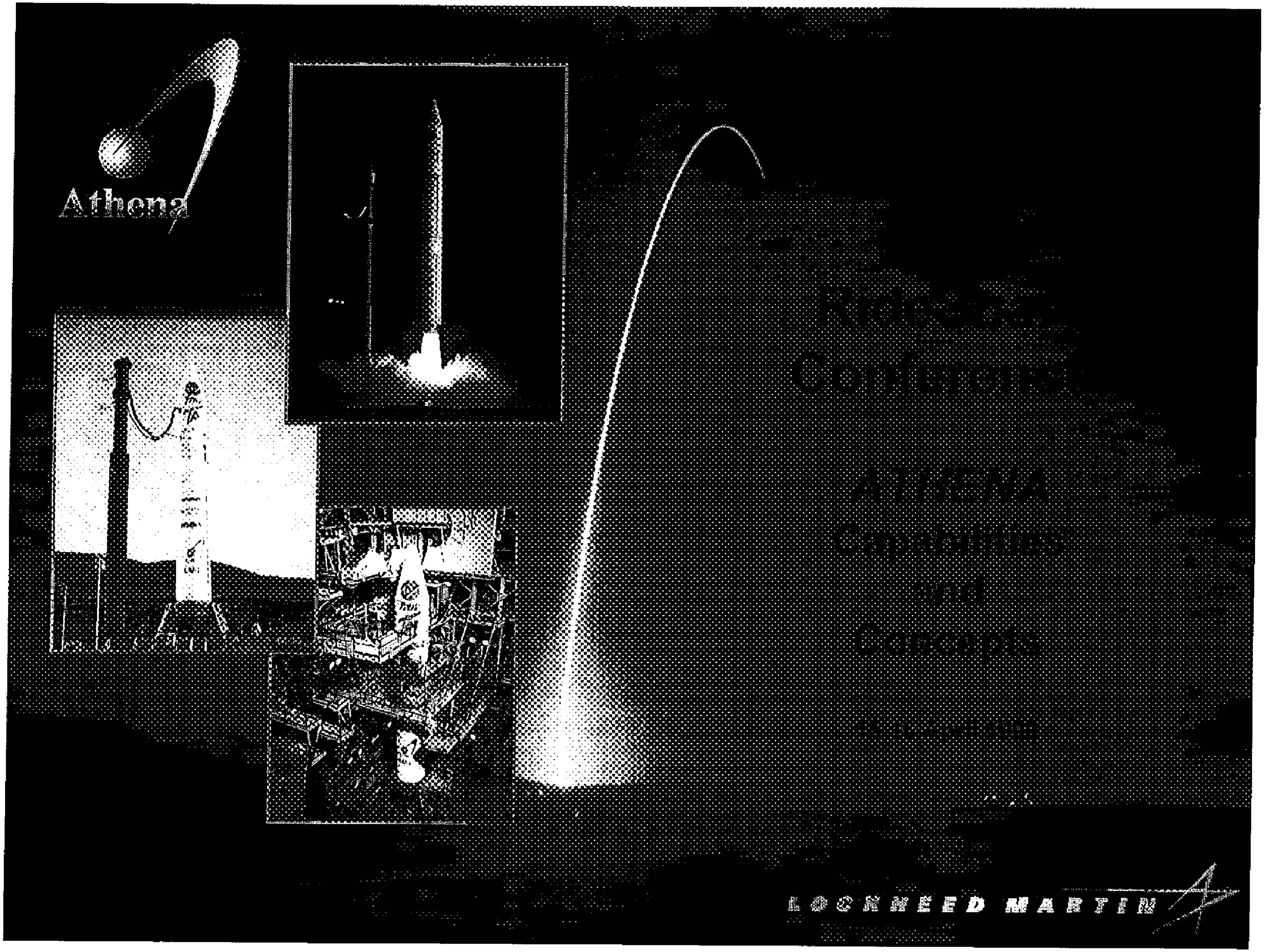
- Head, Department of Space and Climate Physics of UCL
- COSPAR Commission E
- Advisory Panel ESA Space Science Department
- UK Particle Physics and Astronomy Research Council
- Fellow of the Royal Society, Royal Astronomical Society, Institute of Physics & Foreign Norwegian Academy
- Full Member International Academy of Astronautics
- Member International Astronomical Union, American Astronomical Society, American Geophysical Union, IEEE Professional Group on Nuclear Science
- Research Scientist/Member of the Research Laboratory, Lockheed Palo Alto Laboratory,

Spacecraft Key Personnel

Kim Ward - Director SIL (30 plus years)

Kim was one of the founders of SIL in 1984 and has been with the Company ever since. As Technical Director, he was responsible for initiating and overseeing all the sub-system, spacecraft and ground system developments undertaken by the Company. He is now Director of Marketing. Kim has authored or co-authored many papers on his activities including papers on the various sub-systems produced by SIL and numerous papers on small satellites. He is an active member of: the IAA (International Academy of Astronautics) Space Sciences Committee, Sub-Committee for Small Satellites; the UK Space Science Advisory Committee, the UK Space Science Technology Panel; the GERB Project Steering Group; and the SIL representative on ASTOS, the UK Trade Association for space SMEs. Some of his accomplishment include:

- Station Director of the NASA Ground Station in Kenya for the San-Marco-C Italian/American satellite.
- Experiment Operations Co-ordinator, NASA, Goddard Space Flight Center.
- Development for the UK cameras on the International Ultraviolet Explorer satellite.
- Leader of the Ariel VI Troubleshooting Team formed to investigate the Ariel VI spacecraft
- Study Manager for feasibility studies of ROSAT, AMPTE and HIPPARCOS.
- Project Manager for the UK AMPTE spacecraft launched in 1984.


Athena
LOCKHEED MARTIN

RideShare Approaches and Benefits

- Assumed types of rideshares
  - **Co-Manifest**: 2 spacecraft of relatively equal size
  - **Secondary**: Small payload(s) or spacecraft relative to primary
  - **Multi-Manifest**: 2 or more spacecraft of like size and function
  - Different standardized technical and contractual solutions for each
- Provides Users with increased launch flexibility / opportunities
  - Utilize excess payload capacity
  - Standardized payload interfaces / processes
  - Greater manifesting flexibility and efficiency
- Provide more affordable per-payload launch costs
  - Shared launch costs based on mass and volumetrics
  - Minimize non-recurring integration effort and expense
  - Minimize spacecraft shelf life and maintenance costs
- Can serve as price discriminator in competitive bidding

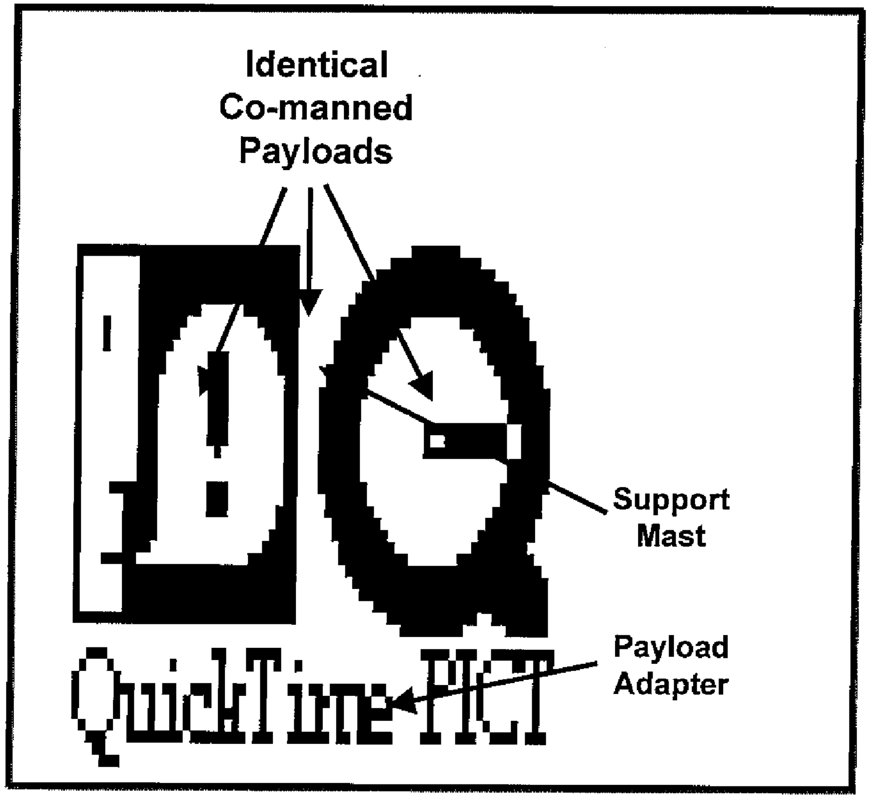
Athena Capacity For Rideshares

- **Athena I to II performance gap allows margin for rideshares**
  - Capability Comparison (lb):

Orbit	Athena IB		Athena IIB
100 nm, 28.5	1800	← Gap →	4400
300 nm, 90	920		2700

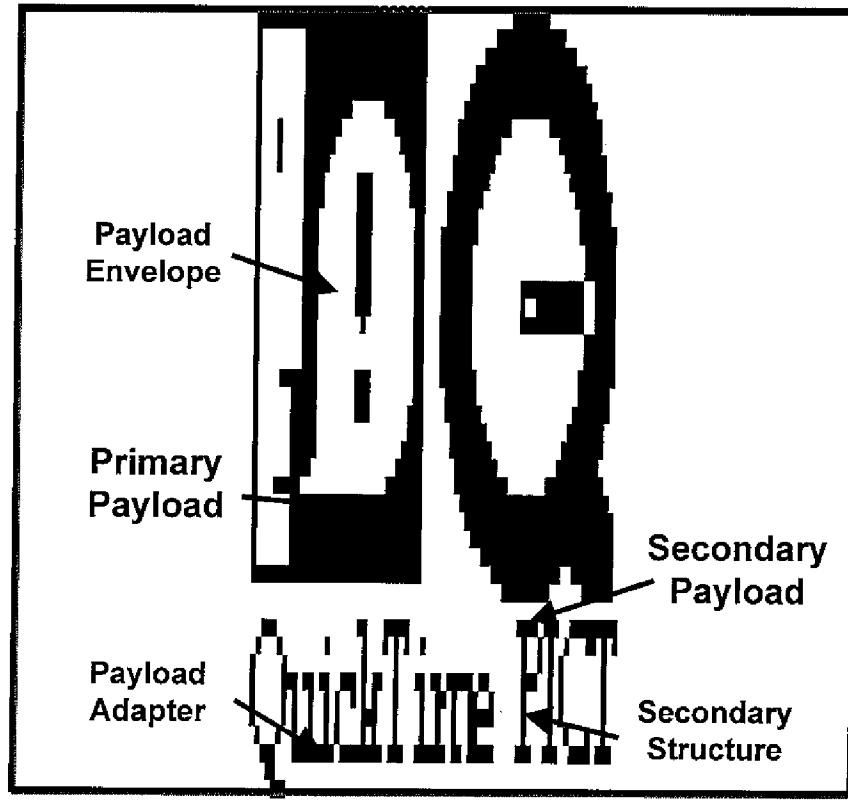
  - Gaps create unused capacity for missions
  - Average performance margin: 15% to 40%
- **Large payload fairing volume**
  - 92"-Diameter in production; Athena I and II
  - 120"-Diameter build-on-need; Athena II only
- **Payload-to-LV Electrical Interfaces**
  - Telemetry: 10 Analogs and 10 Discretes
  - 5 continuity (checkout) loops and 5 separation indicators
  - 8 channels for customer-specified SV commands
- **FASSN Shockless Separation System**
  - Screw-driven decoupling system
  - Greater payload mounting flexibility with fewer dynamic constraints

RideSharing Concepts



Circular Load-Bearing Dispenser

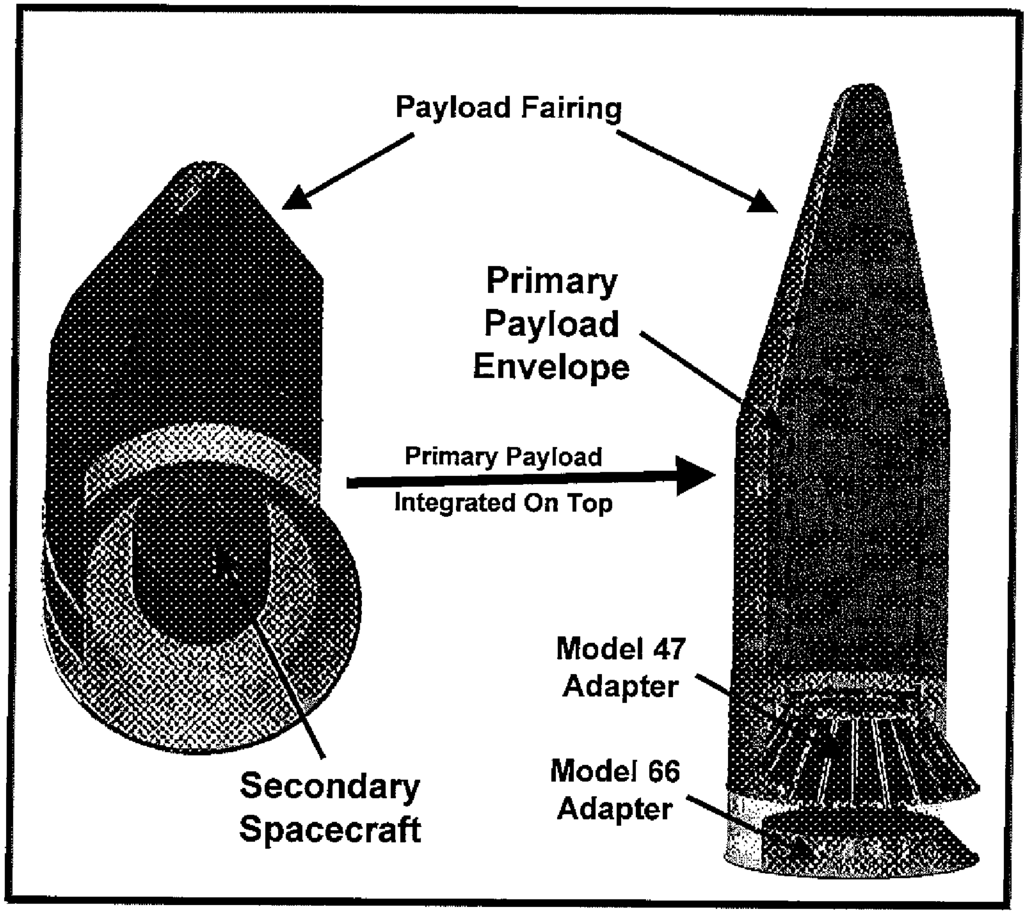
- Vertical mast structure supports 1 or levels of adjacent S/Cs
- Used for identical S/C deployed into constellation



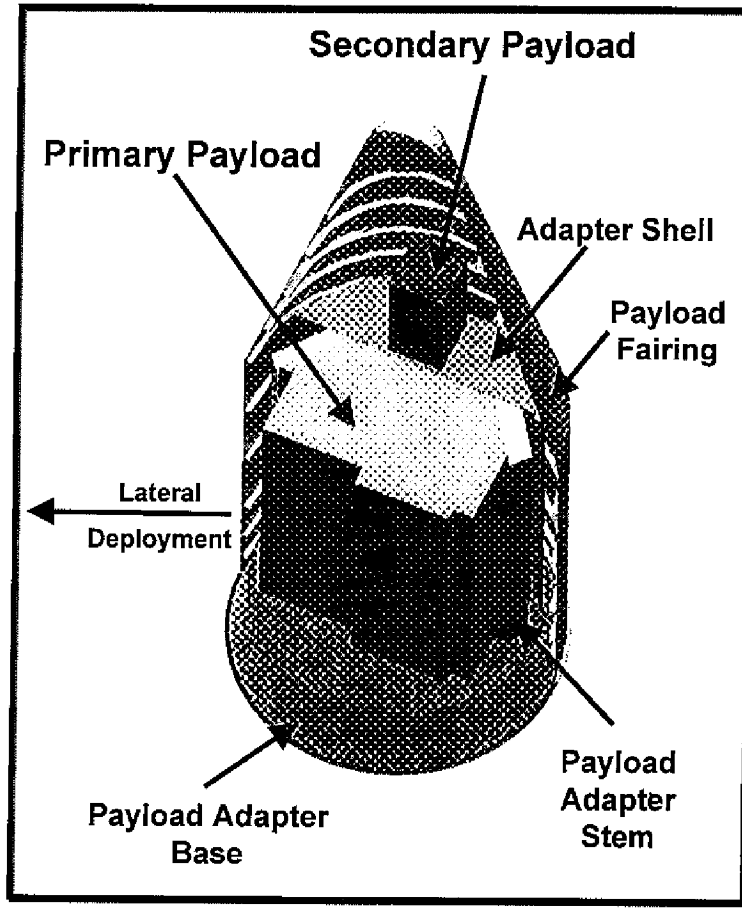
Shelf-Dweller Side Mounting

- Mission-unique shelf for secondaries on adapter outer wall
- Relatively inexpensive
- Pre-work C.G. and coupled loads

RideSharing Concepts (cont)



"Inter-Adapter"
Secondary Spacecraft Mount



"Top-Shelf"
Secondary Spacecraft Mount

RideSharing Challenges

Athena

- Cost of integrating multiples, co-mans or secondaries
  - NRE and recurring cost of integration structures and electrical systems
  - Secondary payload launch budget typically < $1M
  - Cost prohibitive without LMC or USG investment
- Increased contracting risk
  - "Contingent" contracting for first signing party
  - Primary vs. Secondary User rights
- Matching orbits for 2 or more spacecraft
  - Inclination
  - Altitude (mitigated by on-board propulsion)
- Lack of industry standards: electrical, mechanical interfaces
- Launch date/window conflicts
- Spacecraft environment concerns
  - Mutual impacts due to coupled loads
  - Possible electro-magnetic, thermal or shock incompatibilities

Success Requires Industry Standards and User Commitment

Athena/SpaceDev Teaming Pursuit

Athena

- **Pursuing partnership to fly experiments**
  - SpaceDev's SIL stackable bus
  - Athena I, IB and II standard launch service
  - Goal: Lowest-possible per mission cost to the User
- **Cost-efficiency through standardization**
  - Standardized electrical/mechanical LV/bus interfaces
  - 3 or 4 standardized orbits
  - Static launch dates
  - Quantity-buy Athena launch services
- **Multiple experiments per launch (ETR assumed)**

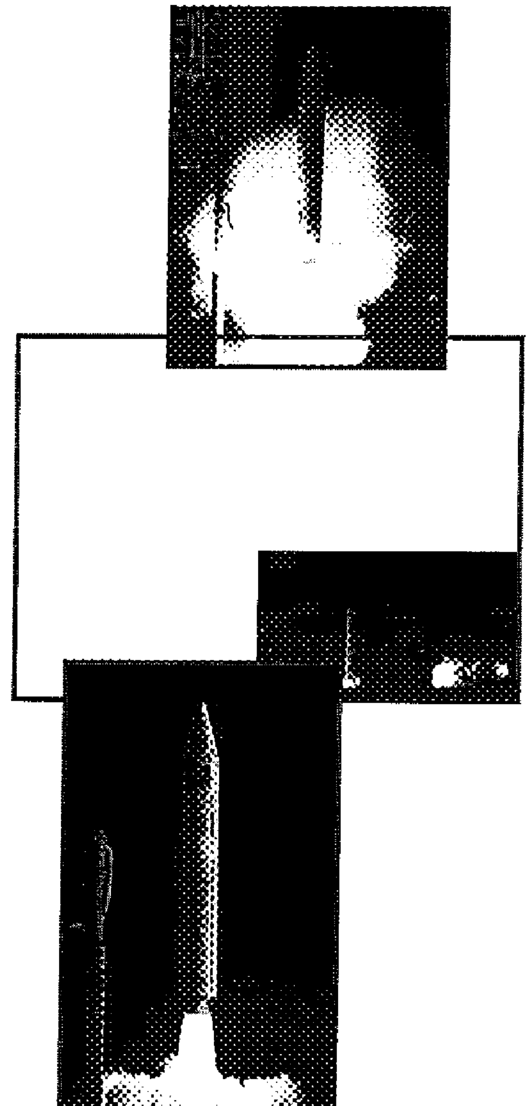
LV Configuration	# S/C Buses	Experiment Capacity
Athena I	4–P's or 2–2L's	8–12 Payloads
Athena IB	4–L's	4 dedicated buses

(Athena II required for some high-inclination missions)

- **Streamlined facilitation of rideshares**
  - Elimination of "primary" spacecraft program constraints
  - Takes LV and SV programs out of the brokering business
  - Affordability stimulates demand

Concluding Remarks

- **Athena Program Viable and Competitive**
  - **Holding cost/price despite sales slump**
  - **3 for 3 in operational launches**
    - Lewis / Athena I mission - 20 Aug 97
    - Lunar Prospector / Athena II mission - 6 Jan 98
    - ROCSat / Athena I mission - 26 Jan 99
    - Sub-system and system performance nominal to date
    - Orbital accuracy to within ~0.5 km, 0.013°
  - **Two sites activated on schedule**
  - **1st launch from Kodiak Launch Complex August 2000**
  - **3 launches currently on manifest, 2 more recently awarded**
- **Ridesharing makes sense provided:**
  - **Matched spacecraft programs are compatible**
  - **Customers willing to assume business risk for LV savings**
  - **Spacecraft integration solutions are standardized**
- **International competition drives price-to-win:**
  - **Domestic: < $2M**
  - **International: < $1M**
- **Athena fits well with SpaceDev for rideshares**
  - **Eliminates "middleman" constraints for Users**
  - **Provides lowest-cost solution**



Orbital

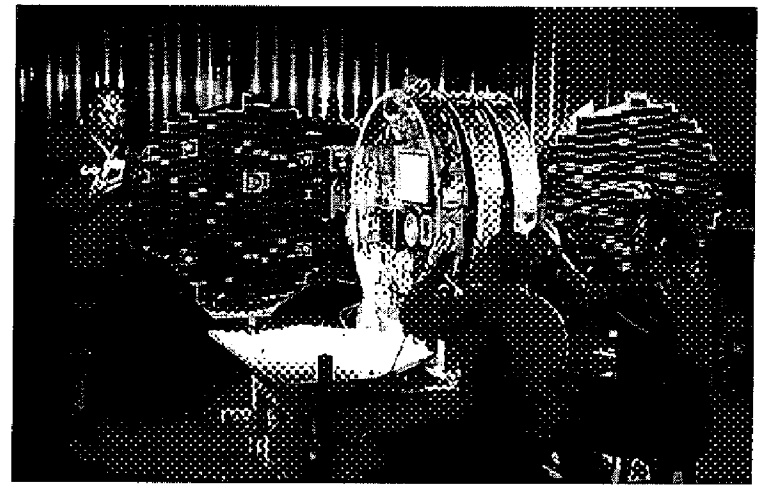
Orbital Spacecraft Buses

Regan E. Howard
Advanced Systems Department
301-428-6091
howard.regan@orbital.com

MicroStar

Orbital

Orbview-1



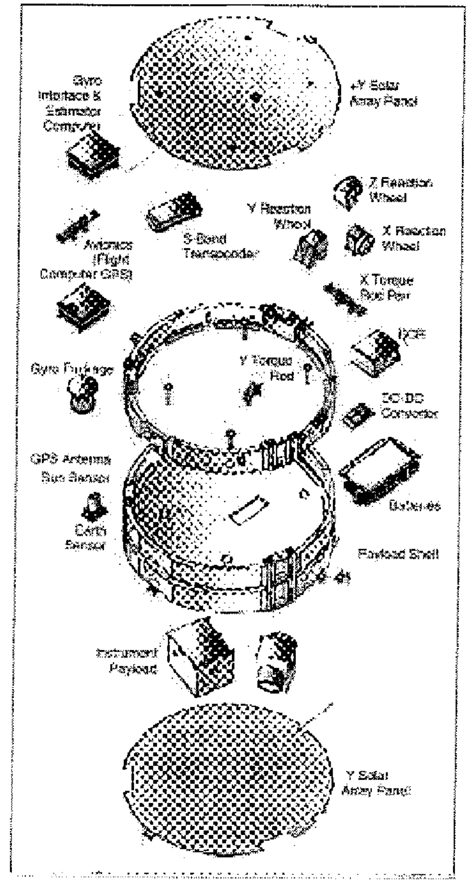
BATSAT

- Designed for stacking in Pegasus or Taurus
- Primary or secondary
- Single string - 3 to 5 year mission life
- 30 Microstars on orbit
- Communications and remote sensing
- In production

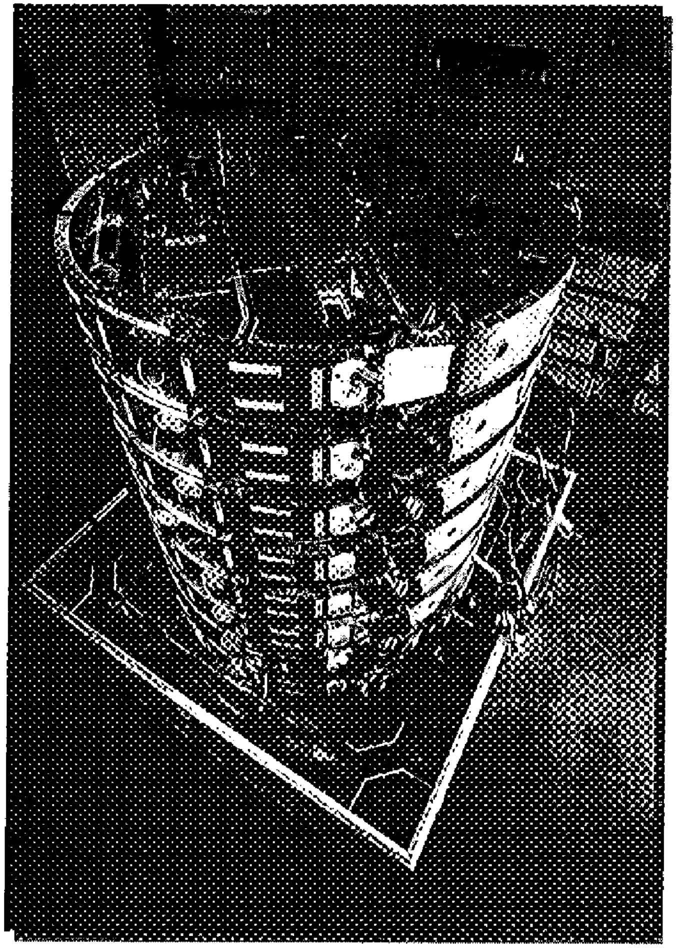
MicroStar Technical Specifications

Orbital

- Core Bus Features
  - Bus Dry Mass....................................40.0 kg
  - Payload Mass Capability.....................68.0 kg
  - Redundancy..Single string
  - Orbit..700-1,000 km
    - All Inclinations
  - Launch Vehicle Compatibility.............Pegasus, Taurus,
    - SELVS I and II
  - Typical Mission Lifetime.....................3-5 Years
  - Delivery...24 Months ARO
- Power Subsystem
  - Payload Power..................................70 W orbit avg..
  - Bus Voltage..14 VDC
    - 28V optional
  - Solar Arrays.......................................2 GaAs
  - Batteries..10 A*hr NiH
- Attitude Control Subsystem
  - Stability Mode.................................. 3-axis
  - Control... ± 1°
    - 0.02 ° per axis pointing optional
  - Knowledge..< 2°
  - Rate/Stability.....................................<0.01°/sec



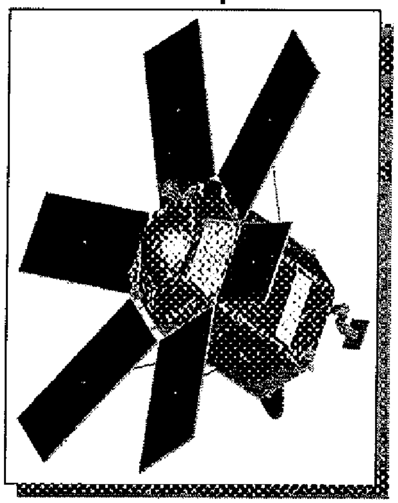
ORBCOMM



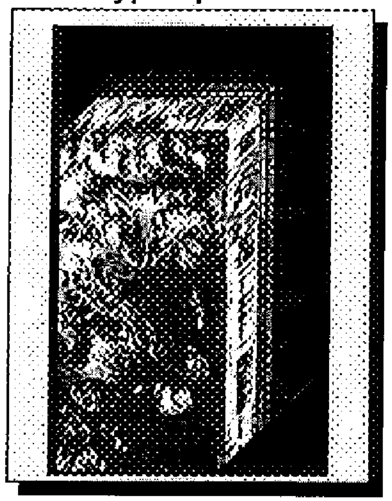
- Customer: **ORBCOMM Global**
- Mission
  - – Narrow Band, 2-Way Data for:
    - Monitoring
    - Paging
    - Tracking
    - Messaging
- Performance Summary
  - – 5 Year Mission Goal
  - – Uplink: VHF (148-150 MHz) at 2400 bps
  - – Downlink: VHF (137-138 MHz) at 4800/9600 bps
- Status
  - – Fully Licensed by FCC and ITU
  - – Financed With ~$400M in Equity, Debt and International Partner Capital
  - – Operational Now With Constellation of 28 Satellites

OrbView-4

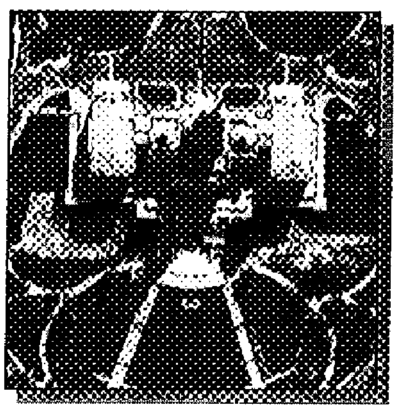
OrbView-4 Spacecraft



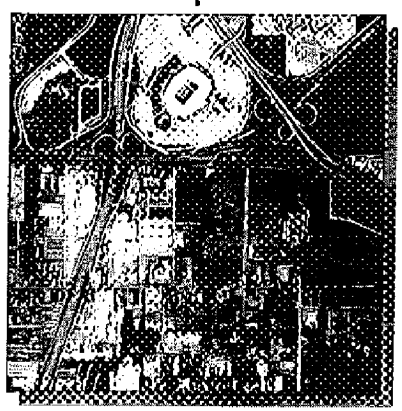
Hyperspectral



Panchromatic

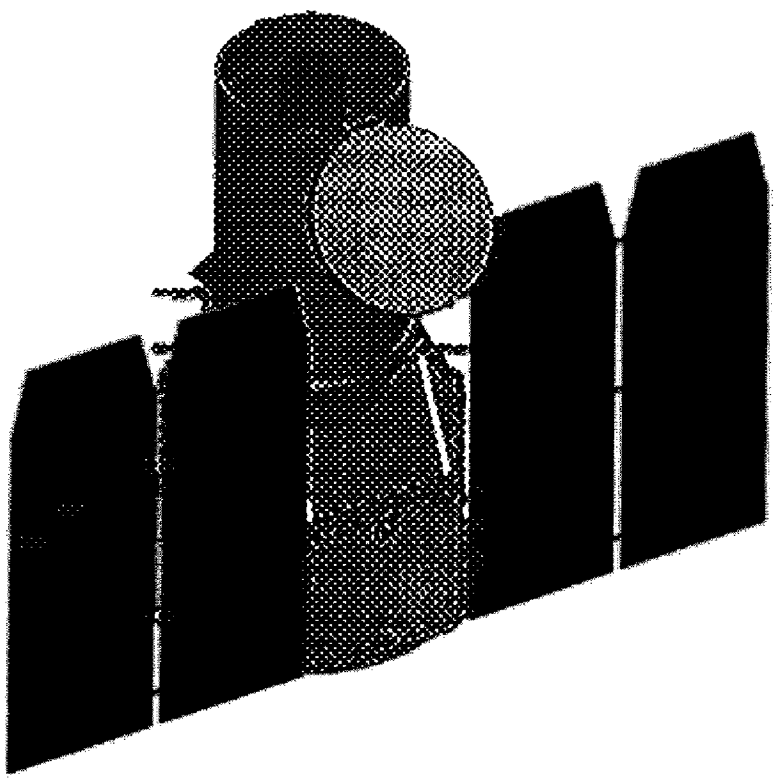


Multispectral



- •Customer
  - –ORBIMAGE
- •Mission
  - –Provide High-spatial Imagery
    - Panchromatic
    - Multispectral (4 Bands)
    - Hyperspectral
  - –Applications
    - National Security
    - Mineral and Oil Exploration
- •Performance Summary
  - –5-year Mission
  - –Orbit, Circular: 705 km, 98°
  - –3-axis Control: ± 5 Arcsec (1σ)
    - Knowledge: ± 3 Arcsec (3σ)
  - –Bus Mass: 290 kg
  - –Payload Mass: 72 kg
- •Status
  - –In Development
  - –Taurus Launch 2Q00

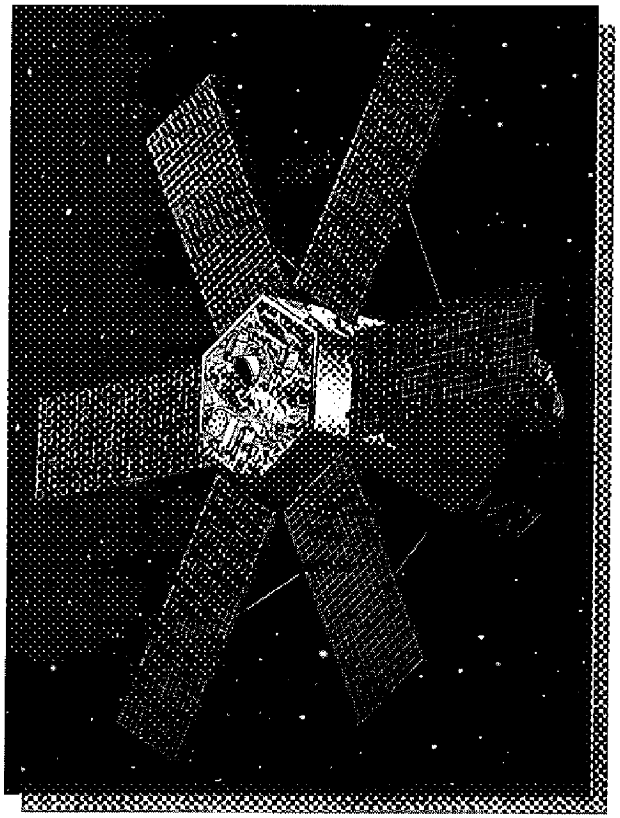
GALEX (Galaxy Evolution Explorer)



- Customer
  - NASA Small Explorer Mission
  - PI: Chris Martin/CalTech
  - Mission Management: JPL
- Mission:
  - UV telescope will perform all-sky survey
  - Investigate origin and evolution of galaxies, stars and heavy elements
- Performance Summary
  - 29 Month Mission
  - 1.2 Arc-min Pointing Accuracy
  - 0.1 deg/sec slew rate
  - Launched 9/01 Aboard PEGASUS XL
  - Mass 254 kg (S/C Plus Instruments)
  - Power 293 WOA array power EOL
  - Orbit 690 km Circular, 28.5° Inclination
- Status
  - Phase C/D

SAVE/SOLSTICE

Orbital



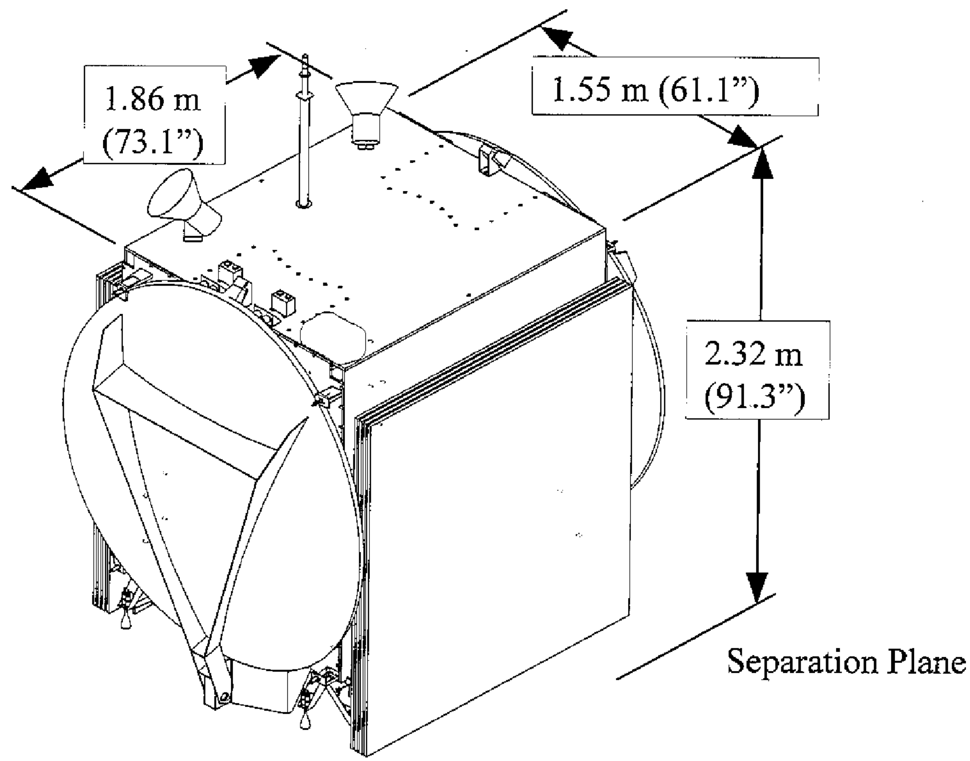
- Customer
  - University of Colorado @ Boulder, Laboratory for Atmospheric & Space Physics
- Mission:
  - Continue the Solar Ultraviolet Spectral Irradiance Data Set
  - Measure Solar and Stellar Irradiance Variations
  - Investigate Their Effects on the Earth's Climate
  - SAVE is Part of NASA's Ongoing Earth Observation System(EOS) Program
- Performance Summary
  - 6 Year Design Life (Redundant components)
  - 0.24 Arc-min Pointing Accuracy
  - 1 deg/sec slew rate
  - Launched 7/02 Aboard PEGASUS XL
  - Mass 237 kg (S/C Plus Instruments)
  - Power 707 WOA array power EOL
  - Orbit 660 km Circular, 40° Inclination
- Status
  - In Phase B

GEO Quick Ride

Orbital

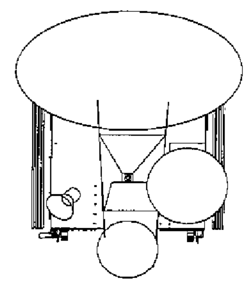
- Orbital Was Awarded GEO Quick Ride Study Contract
  - Targeted at 2001 and Beyond Satellite Capabilities
  - Mid-Term Held in March 1999
  - Study Will Be Completed in May 1999
- Basis of Study:
  - NASA Science is Interested in Piggy Backing on Commercial Missions to GEO
- Orbital's Star-2 Bus Is Being Used For The Study
  - Star-2 Bus Is Capable of Accommodating Instruments Over the Entire Range Defined By NASA
  - Power Margins Can Be Exploited In The Accommodation of Instruments
  - Typical Configuration With Side Mounted Communication Payload Antenna Provide Excellent Field-of-View For Instruments
- Orbital Is Providing NASA With a Defined Set of Instrument Accommodation Parameters

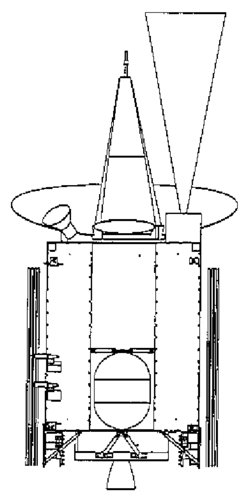
Star-2 Physical Size

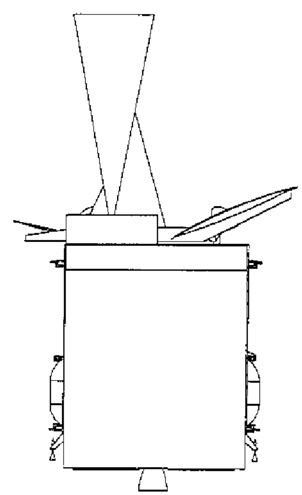


Secondary Payload Fields of View

- With Earth Panel Mounted Antennas, a Variety of Earth Panel Mounting Locations Are Available With Clear Nadir Pointing 20° (Full Angle) Fields of View:







Ball Aerospace
& Technologies
Corporation

Small Platforms for Secondary Payloads

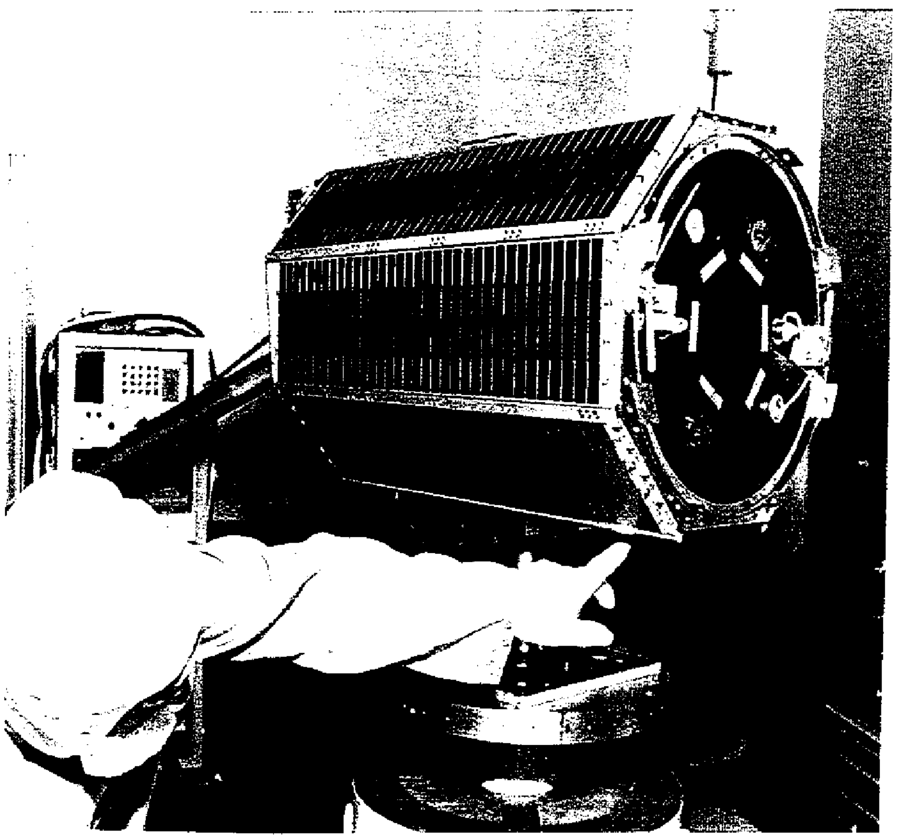
Terry Schrepel
Launch Integration Manager
(303) 939-5887
tschrepel@ball.com

Sensor Platforms

- SSA
- GTD
- DARPSAT
- GFO
- RS2000
- Multi-spectral Thermal Imager
- QuickScat

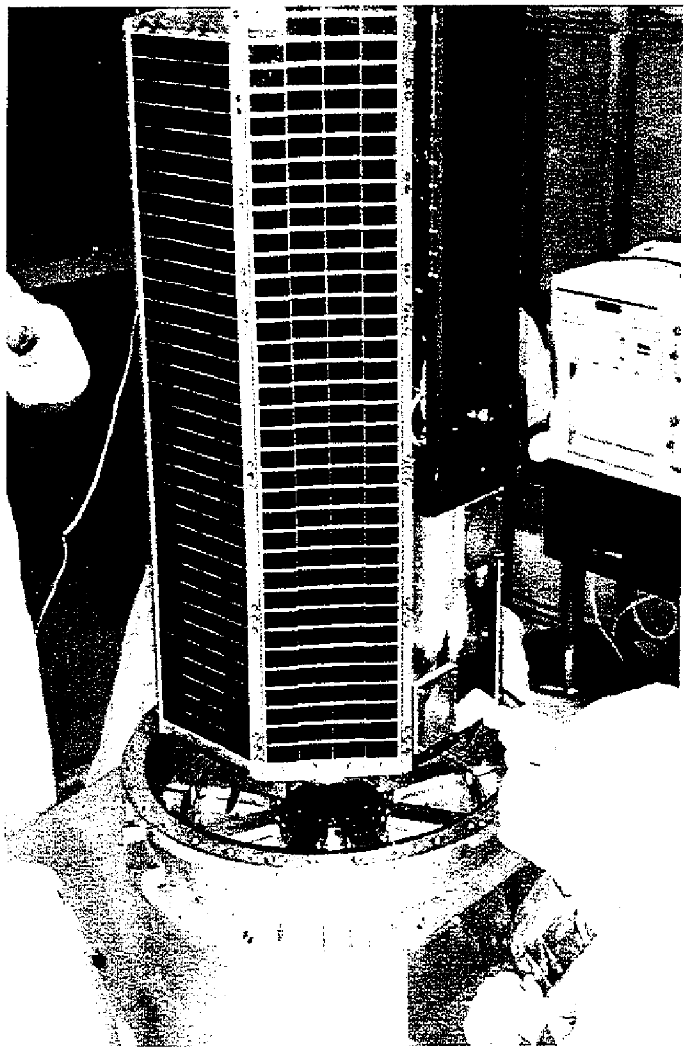
Ball Aerospace
& Technologies
Corporation

SubSystem "A" (SSA)



- Shuttle launched - GAS Can
- Mission: Classified
- Customer: Classified
- Single-string
- Spin-stabilized
- 19" dia x 35" H
- 119 kg spacecraft
  - 23 kg payload
- 29 W array BOL
  - 55 W peak for payload
- SGLS (encrypted)
  - 32 kbps downlink
- Status: Launched 1989
  - 1 yr life/3.5 actual

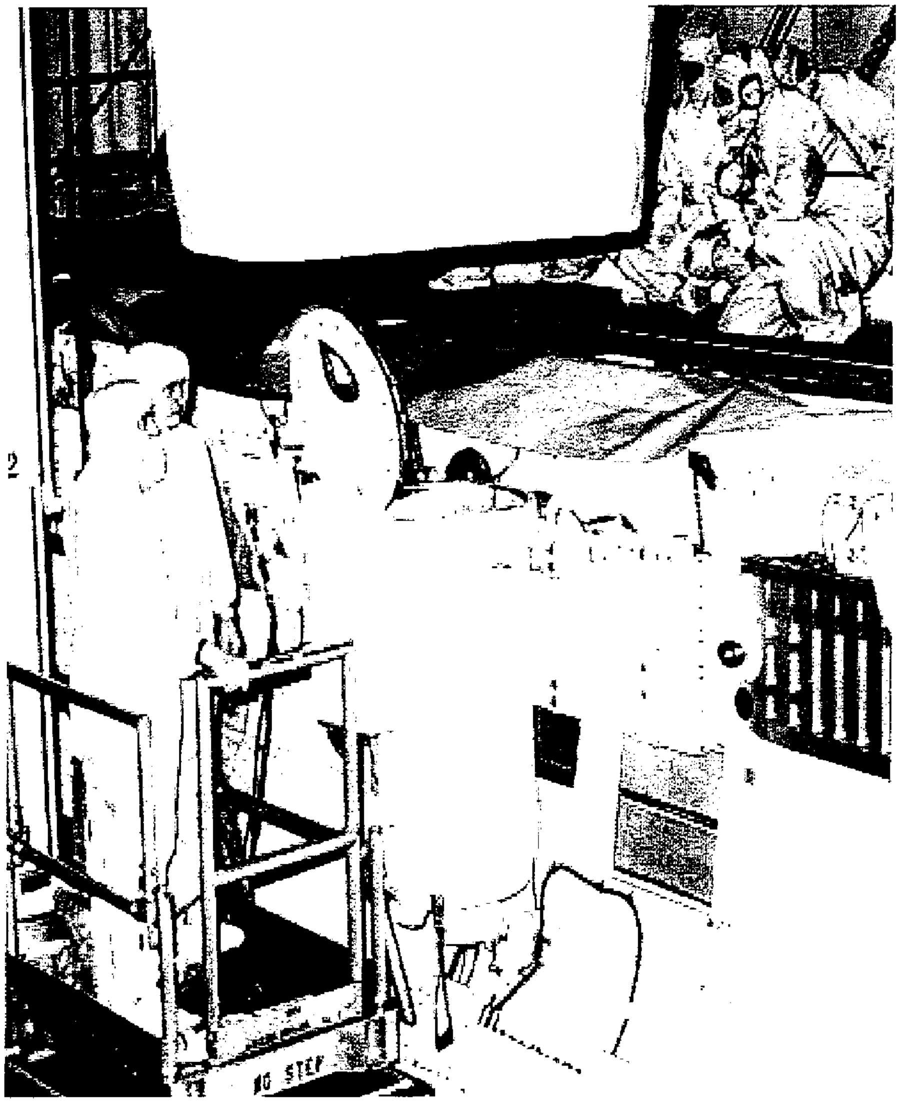
"G" Test Demonstration (GTD)



- Shuttle launched - GAS Can
- Mission: Classified
- Customer: Classified
- Single-string
- Spin-stabilized
- 19" dia x 40" H
- 125 kg spacecraft
  - 20 kg payload
- 29 W array BOL
  - 57 W peak for payload
- SGLS (encrypted)
  - 32 kbps downlink
- Status: Launched in 1991
  - 1 yr life

Ball Aerospace
& Technologies
Corporation

Multi-Purpose Experimental Canister (MPEC)



- Ball-built dispenser for SSA and GTD

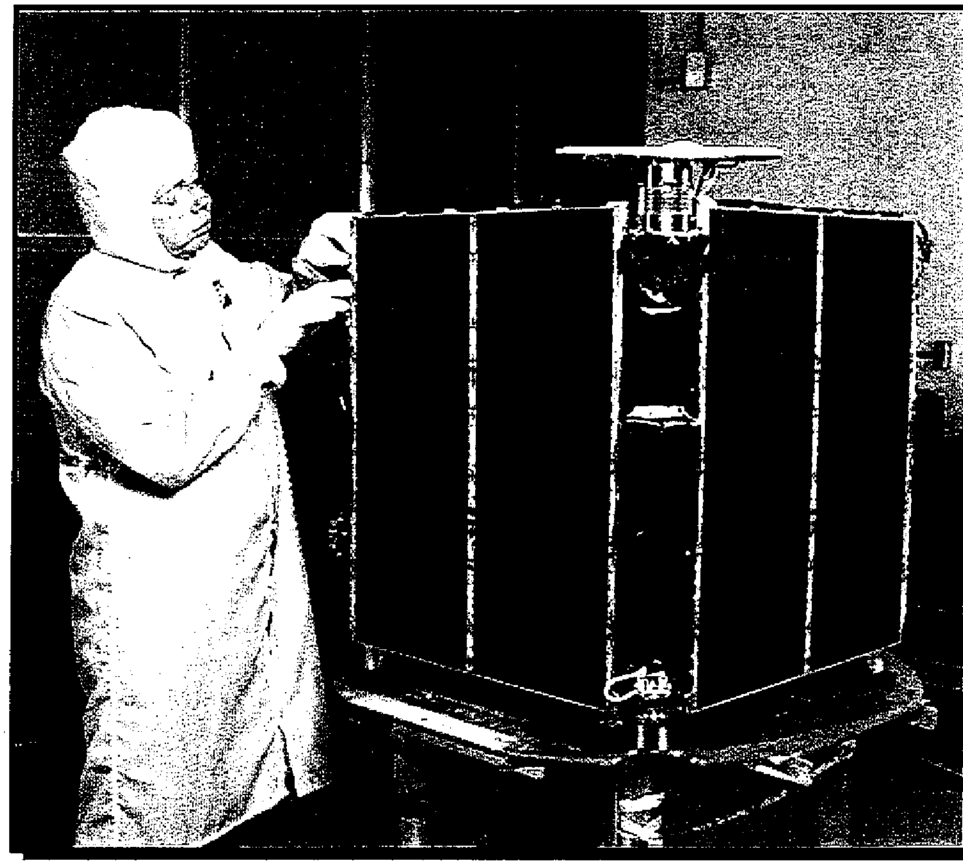
Ball Aerospace
& Technologies
Corporation

DARPASAT

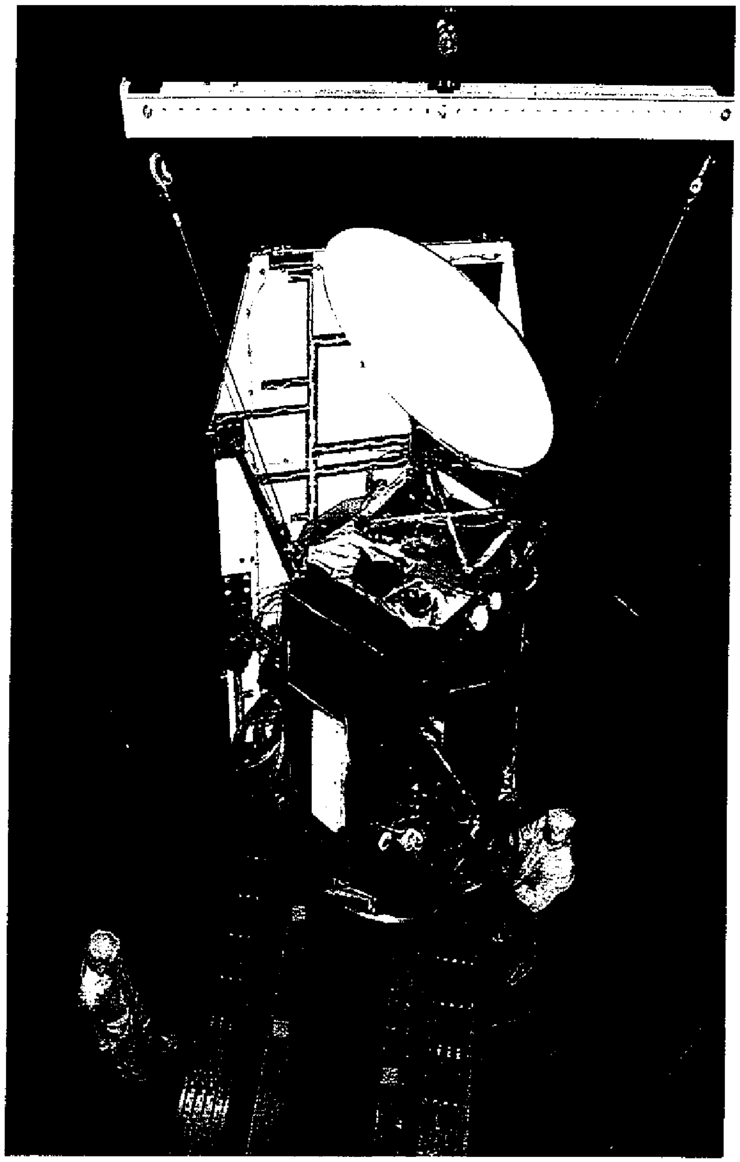
- Mission: Classified
- Lifetime: 1 yr. w/3 yr. Goal
- Bus Weight: 437 lbs.

  195 kg spacecraft
  - 39 kg payload
- Launch Vehicle: Taurus

  dual launch with STEP
- 31" X 31" X 30"
- 70 W array
  - 107 W peak for payload
- Status: Launched March 1994, still operational



GFO

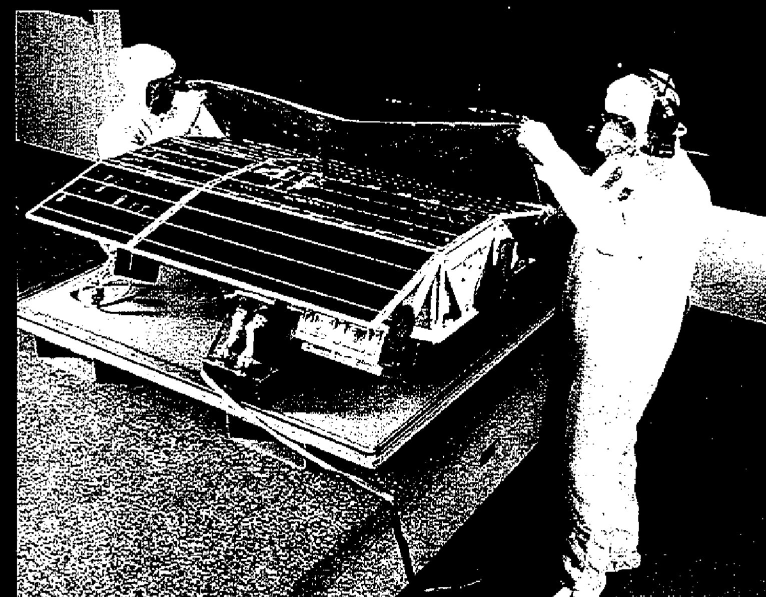


- Taurus launch
- Fully redundant
- 3-axis stabilized
- 40" x 40" x 40"
- 350 kg spacecraft
  - 60 kg payload
- 319 W array BOL
  - 126 W for payload
- SGLS
  - 4 Mbps downlink
- Status: Launched Feb. 1998
  - goal 1 year in XX year goal

Aerospace Systems Division

LOSAT-X

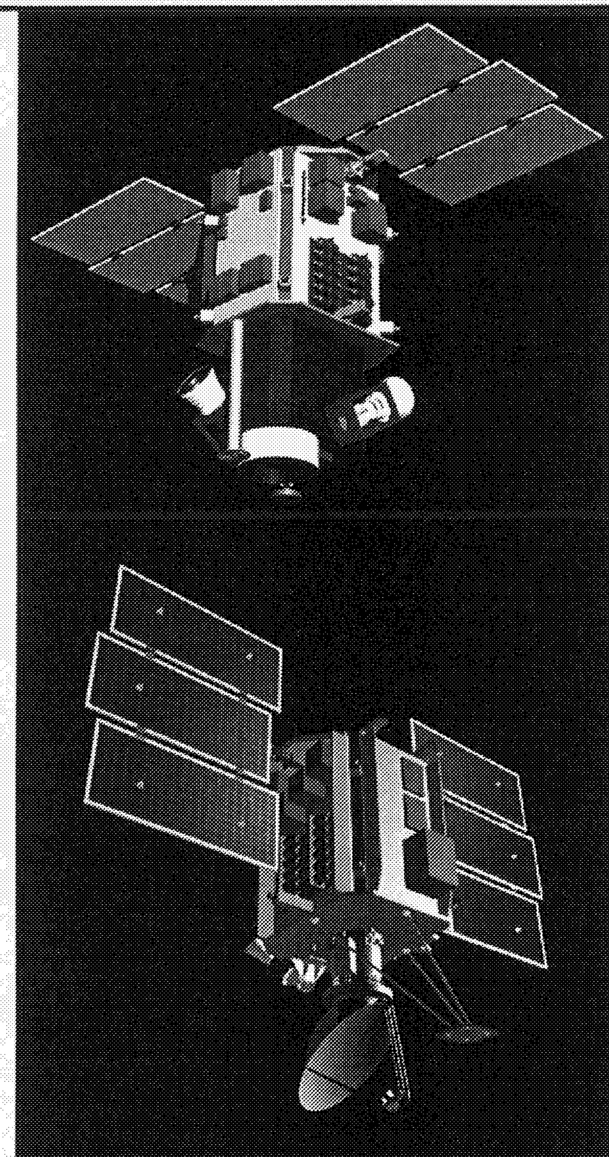
- Customer: Strategic Defense Initiative Organization
- Ball Role
  - Turn-key Mission: satellite, launch vehicle integration, one on-site mission ops center, mission ops
- Mission
  - Obtain data from and perform calibration on sensors used on Brilliant Pebbles
- Unique, low-cost design
  - No redundancy - 3 month life on orbit
  - Bus: 148.3 lb, 4.3 x 3.3 x 1.5 ft
  - Delta II
  - Price $M



Ball Aerospace
& Technologies
Corporation

BCP 2000

- Design Orbit: 600 Km at 52.5° Inclination
  Sun Synchronous Orbits examined
- Launch Vehicle: Multiple (Taurus Compat.)
- Payload Mass: 604 pounds
- Payload Power: 430 Watts Average
  Mission Scenario Dependent
- ADCS: 3 Axis Stabilized/Reaction Wheels,
  Gyros, Star Trackers, GPS
- Pointing Accuracy: .03°/axis
- Design Life: 5 years, Redundant
- Data Storage: 137 Gbits
- Propulsion: Hydrazine
- Downlink: 4, 16, 256 Kbps X-Band
  320 Mbps X-Band

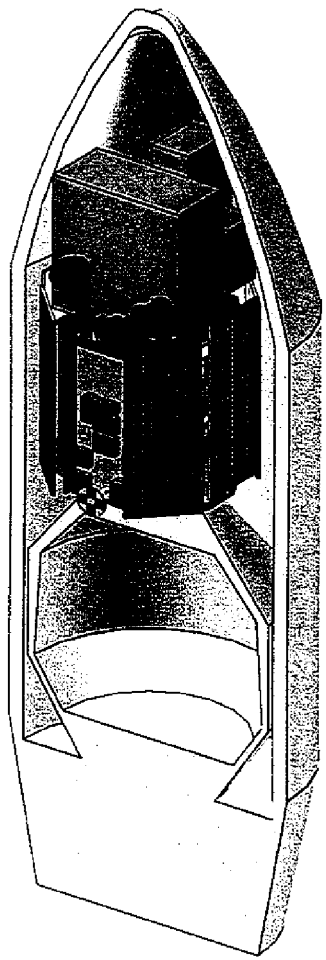


Designed as an Earth Observation Satellite

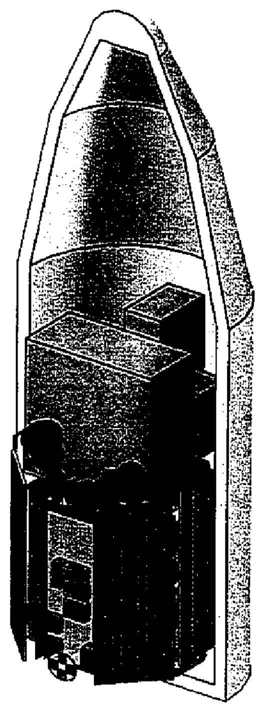
Ball Aerospace
& Technologies
Corporation

Multiple Payloads - Various Launch Vehicle

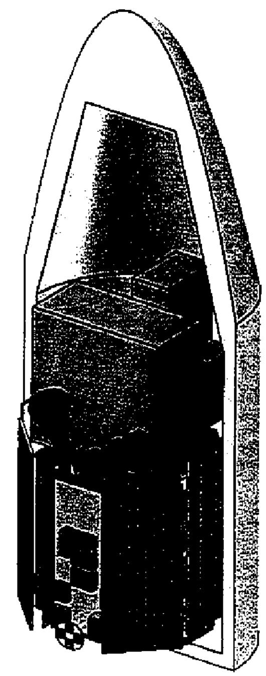
The RS2000 can accommodate multiple payloads using an instrument module and can be co-manifested on a Delta-II



Delta II w/ DPAF



Taurus

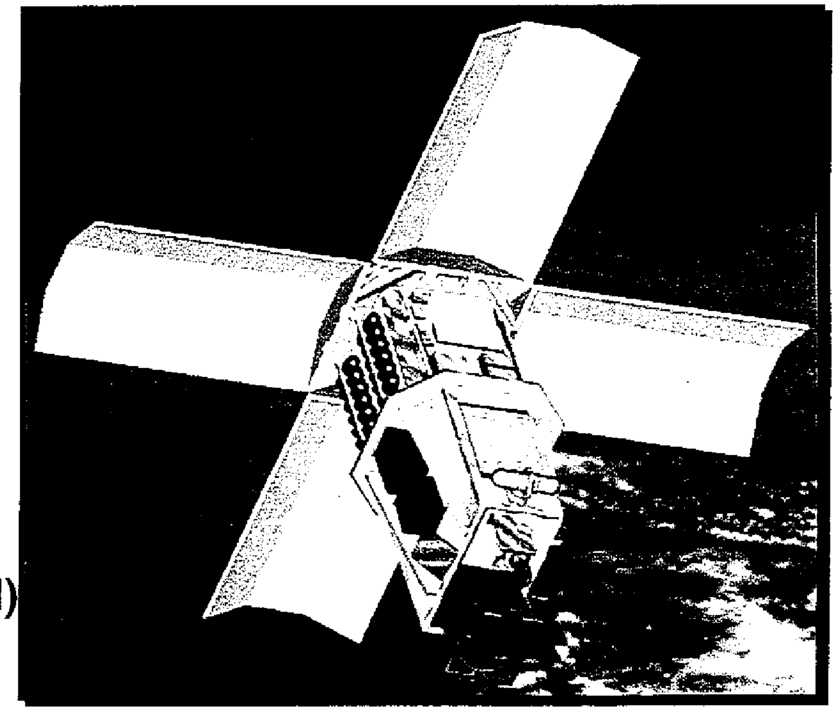


Athena II

Ball Aerospace
& Technologies
Corporation

Multi-spectral Thermal Imager (MTI)

- Design Orbit: 525 Km; Sun Synchronous
- Launch Vehicle: Taurus
- Payload Mass: 550 pounds
- Payload Power: 271 Watts Average
- ADCS: 3 Axis Stabilized/Reaction Wheels, Gyros, Fine Sun Sensor, Horizon Scanner
- Pointing Accuracy: <.35°
- Life Time: 1 yr. w/3 yr. goal
- Data Storage: 2.8 Gbits
- Propulsion: None
- Downlink: 1, 2, 4, 8 Mbps Mission data(S-Band)
  2 and 16 Kbps S/C data only (UHF)



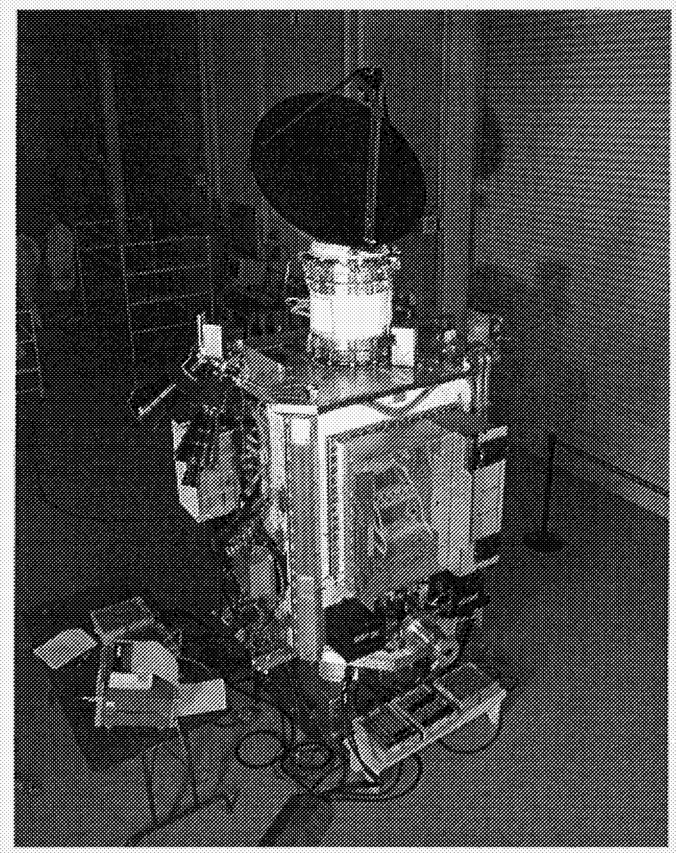
Customer: Sandia National Laboratory

Status:

Ball Aerospace
& Technologies
Corporation

QuickScat - RS2000 in Action

- **NASA Quick Scatterometer**
- **Mission: Record sea surface wind speed and direction**
- **Lifetime: 2 yrs. W/ 3 yrs expendables**
- **Bus Weight: 650 kg (including** propellant)
  - 220 kg payload mass
- **Launch Vehicle: Titan II**
- **803 km sun-synchronous orbit**
- **2 - 3.2 square meter solar arrays**
  - 255 Watts orbit average
- **Status: Waiting for launch**
  - Currently scheduled for May 29th

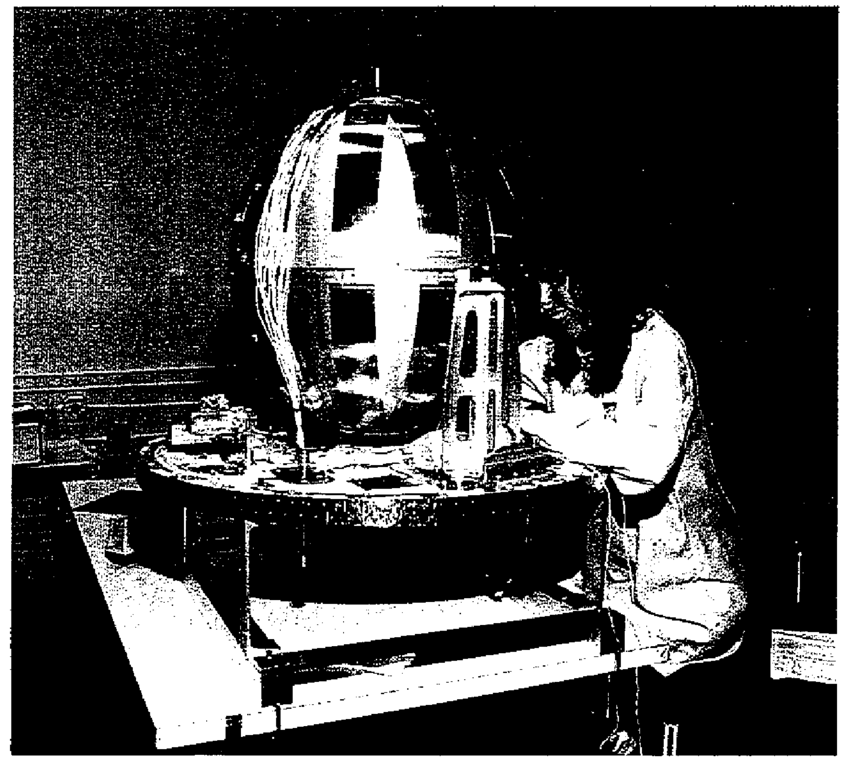


Modification of RS2000 Bus

- **Attitude Control System**
  - Pointing Accuracy: <0.3 deg; (3s) per axis
  - Pointing Knowledge: <0.027 deg; (3s) per axis
- **Transmit/receive rates CMD/TLM**
  - 4 and 256 kbps downlink
  - 2 kbps uplink
- **Payload Data**
  - 2 Mbps transmit rate
  - S-band frequency

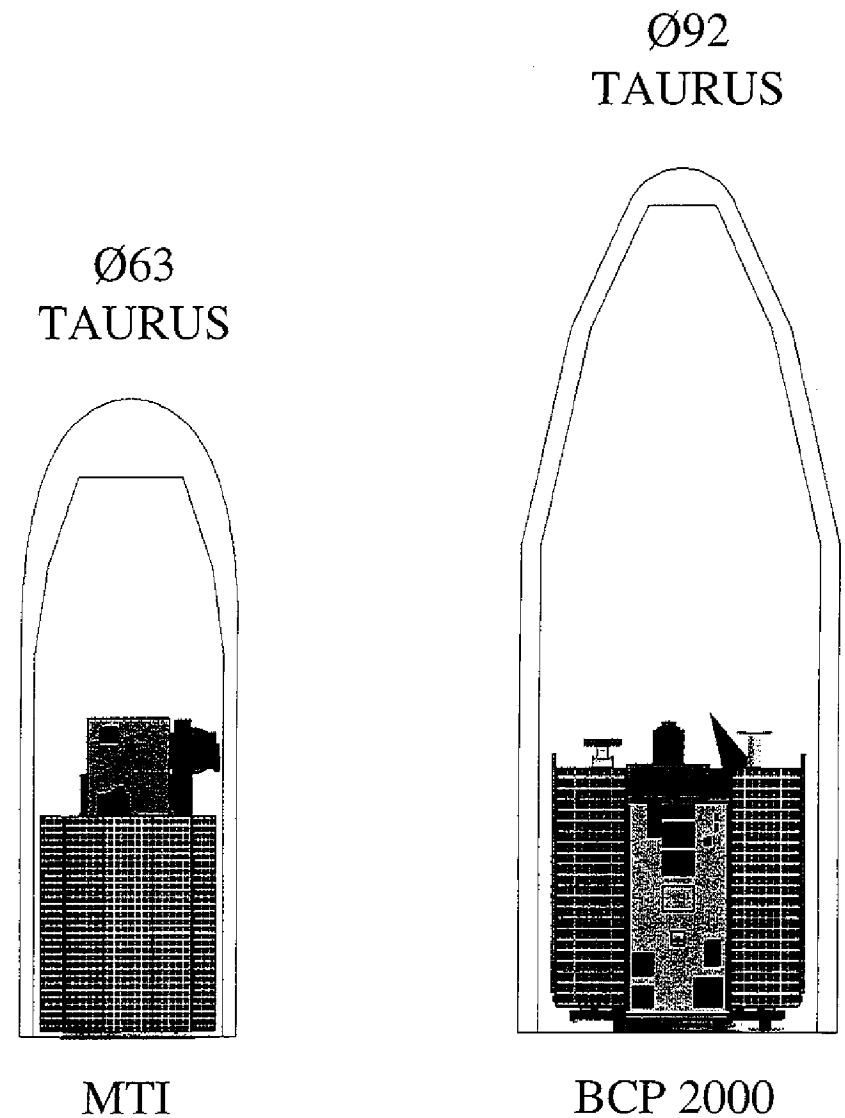
Increase Propulsion System

- **System type:**
  - Hyrdazine
  - 4 thrusters 4.4 Newtons each
  - 76 kg of propellant
- **Delta-V capability: 62 m/s**



Ball Aerospace & Technologies Corporation

Spacecraft/Fairing Configurations



Ball Aerospace
& Technologies
Corporation

Secondary Payload Platforms

- Ball has concept designs for low cost secondary platforms for both 3 axis pointer and stabilized spinner
- Inquires for these platforms are welcomed

Lockheed Martin Missiles & Space (LMMS) Smallsat Capabilities

RideShare Conference

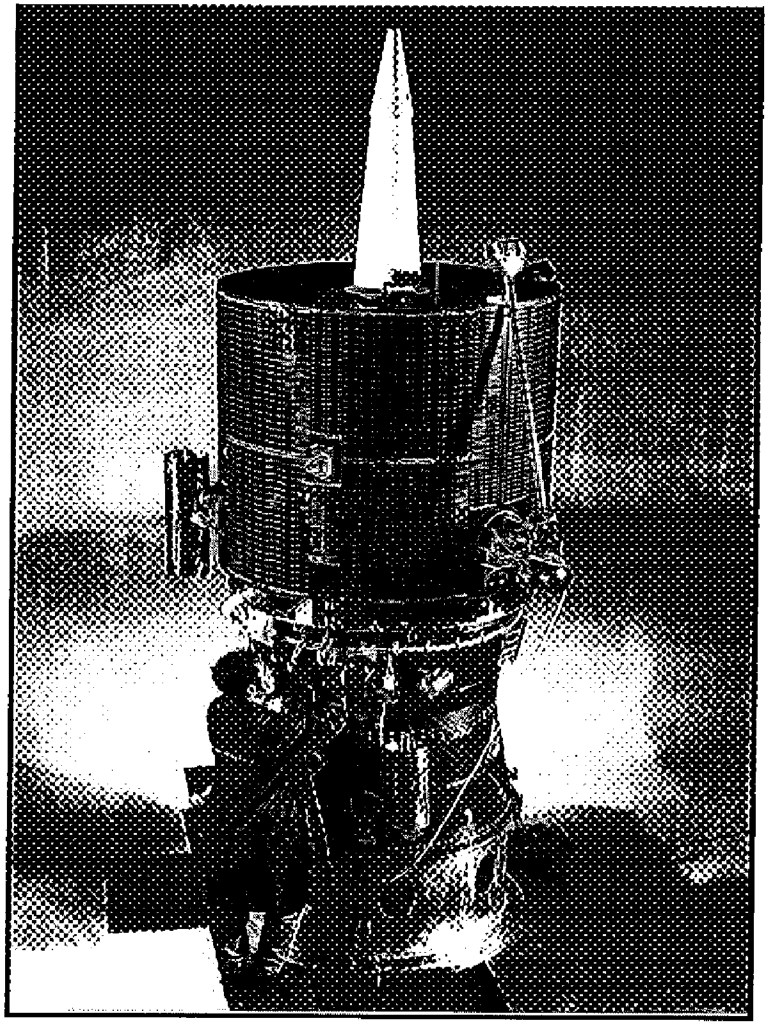
April 15, 1999

Ed McNamara
ed.mcnamara@lmco.com
408-742-2996

LMMS Smallsat Capablity

- LM100™ Class Busses
  - Lunar Prospector baseline
  - IMAGE ‘stretched’ version
  - Gravity-Probe B ‘smaller’ version
- LM700™ Class Busses
  - Iridium baseline
- LM900™ Class Busses
  - CRSS (Ikonos) baseline

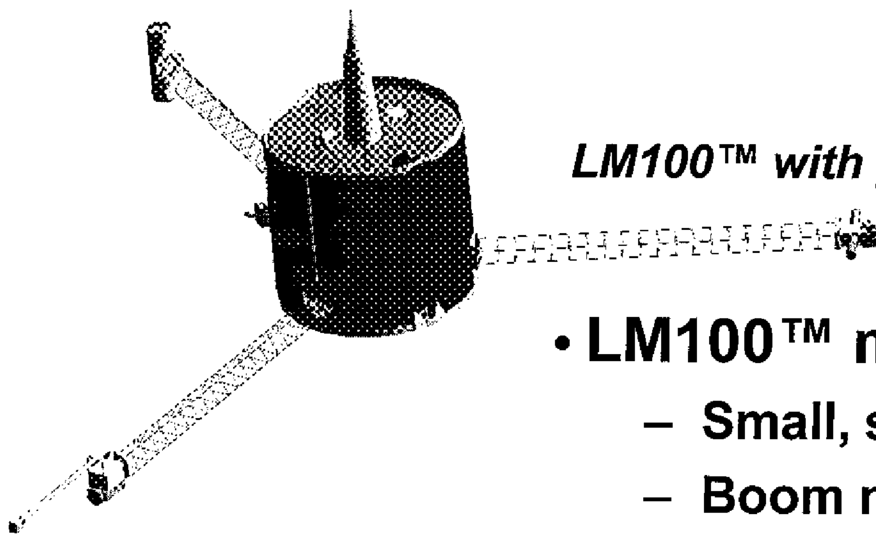
LM100 ™ Spacecraft Bus



The Lunar Prospector being prepared for acoustic test.

Introduction

- LM100™ is derived from the *Lunar Prospector* spacecraft developed for NASA



LM100™ with payload masts deployed.

- LM100™ mission suitability:
  - Small, spin stabilized spacecraft
  - Boom mounted payloads
  - Payloads isolated from spacecraft

Launched: 6 Jan '98 on Athena 2 booster

Lunar Prospector Mission Overview

- Discovery Mission: Deliver science data to user community and demonstrate viability of the *"faster, cheaper, better"*
- Purpose: Lunar science and exploration to include crustal composition mapping, magnetic and gravity field maps, quantify polar ice deposits, search for evidence of lunar outgassing
- Baseline Mission: 1 year, 100 km lunar polar orbit
- Extended Mission: 7 month, 30 x 30 km circular orbit
- Payload Description: 5 omni directional science instruments, packaged as three independent payload elements
- Payload Accommodation:
  - 3 x 250 cm deployable longeron masts
  - 24 kg for science instrument (SI) packages (8 kg per mast tip plate)
  - 17 watts continuous power
  - Precision thermal control for Gamma Ray Spectrometer SI

Lunar Prospector Currently in Lunar Orbit

LM100™ Mission Capability

- Small scientific payloads to GEO, LEO* and lunar orbits
- 3 year mission life
- 141 kg dry mass, 300 kg launch mass
- DSN or TDRSS compatible S-Band CCSDS compatible communications
- Spacecraft and payload equipment mounting to primary bus structure. Ample area for installing electronics units
- Orbit maintenance provided by propulsion system.
- Upper stage compatibility (Star37 series solid rocket motor)
- 24 month schedule from ATP to delivery

*LEO orbit capability limited by ground station availability or on-board data storage capability.

Flexible spacecraft platform for small scientific payloads

LM100™ System Capabilities

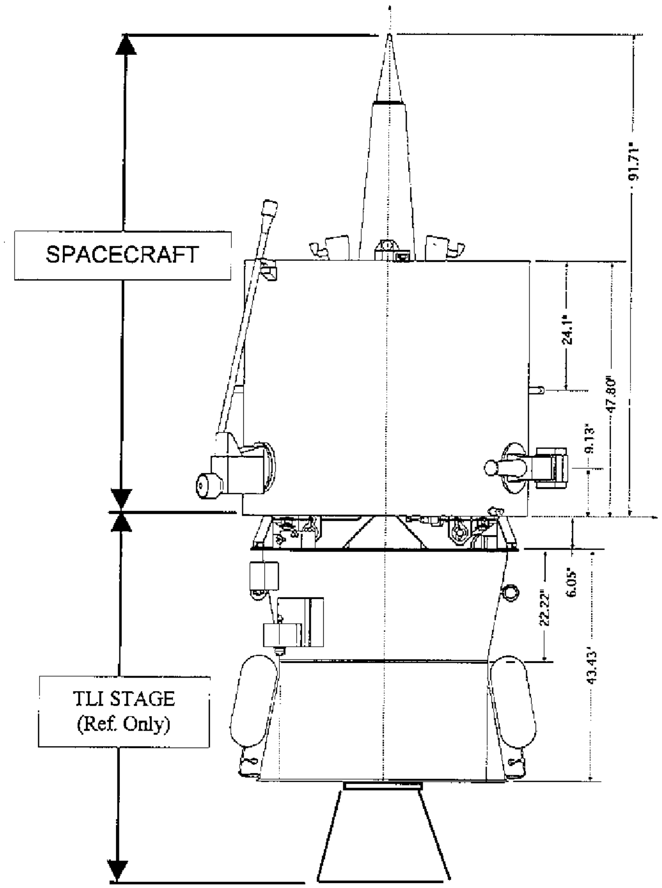
- **Structures & Mechanisms**
  - Graphite/Epoxy primary and secondary structures: >12 Hz lateral and >30 Hz axial
- **Electrical Power**
  - Unregulated 28±6 Vdc system, 230 watt BOL solar array, single 5 Ahr NiCad battery
- **Thermal control**
  - 3 year design life, blankets and coatings, redundant heater circuits
- **Propulsion**
  - Hydrazine monopropellant, system $\Delta V = 1430$ m/s
- **Attitude Control**
  - Spin Stabilized: 1.0° attitude knowledge, 2.0° spin axis pointing, 1.0° spin axis offset
- **Communication**
  - S-Band : 300 and 3600 bps down-link, 250 bps up-link; CCSDS format
- **Ground System and Software**
  - Vehicle commanding, telemetry processing for attitude determination and spacecraft healt and status. 24 hr monitoring, DSN and GSFC navigation support.

Simple, reliable spacecraft with minimal operational requirements

LM100™ Configuration

- Lunar Prospector / LM100™ configuration with Trans-Lunar Injection (TLI) Stage.
- Launch configuration with payload booms stowed.
- Basic envelope: 241 cm long, 205 cm dia.
- 3 pt Spacecraft separation system, easily adapted to marmon clamp.
- Launch vehicle compatibility:

  Athena 1, Athena 2, Taurus, Delta, Atlas



A small, reconfigurable spacecraft.

IMAGE System Changes (from LM100™)

SPACECRAFT OVERVIEW
- Near Autonomous Operation
- Multiple Science Capabilities
- Data Storage and Playback

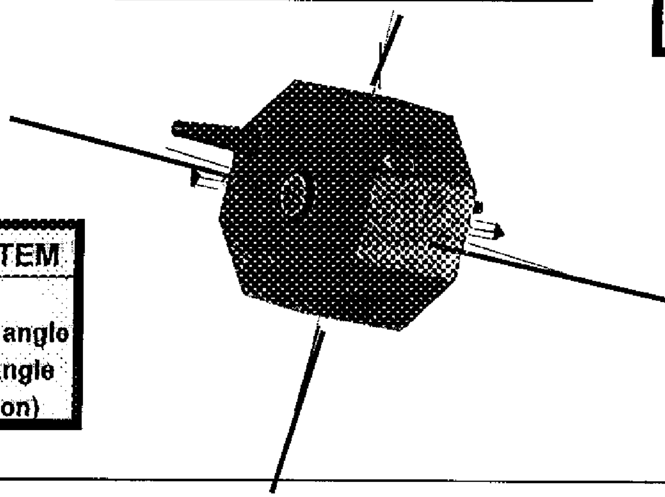
COMMUNICATIONS
- 2 OMNI II antennas
- 2 RF Switches

STRUCTURES
- Aluminum honeycomb panels and gap shielding for EMIEMC
- Flat Panel solar arrays
- Modular payload deckplate

ATTITUDE CONTROL
- Star tracker provides autonomous attitude determination
- Torque rod controls both spin axis orientation and spin rate
- Magnetometer provides magnetic field orientation reference

THERMAL CONTROL
- Heat pipes through P/L dock to perimeter radiators
- Software controlled heaters

ELECTRICAL POWER SUBSYSTEM
- 21 AH Battery dominated bus
- >320 watt SA capability at zero beta angle
- >230 watt SA capability at 67° beta angle
- >120 KHz SA current (shunt regulation)

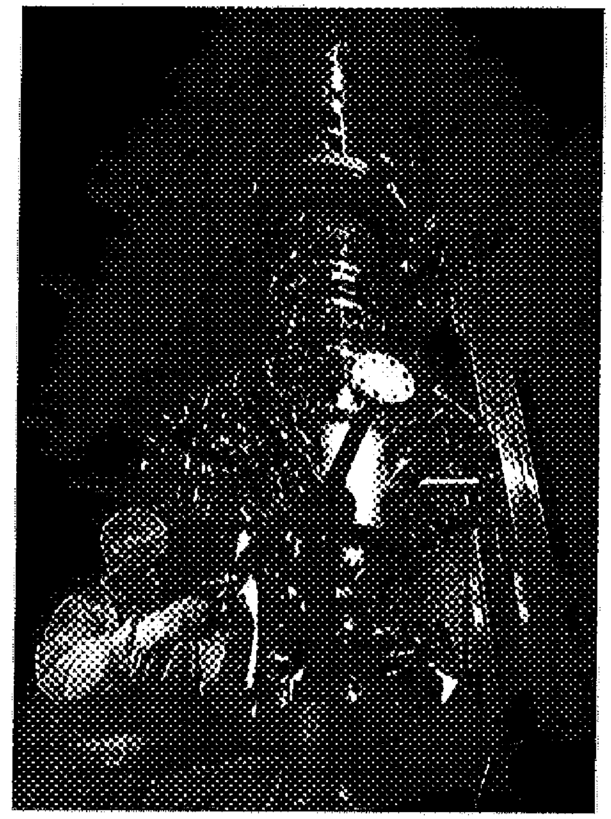


COMMAND & DATA HANDLING
- R6000 based System Control Unit hosts flight software
- COP-2 compatible command uplink
- AOS CCSDS compatible telemetry downlink
- FSW functions include attitude control, general telemetry monitoring, power management and thermal control

System modifications provide robust enhanced capabilities

Small Spacecraft Configurations

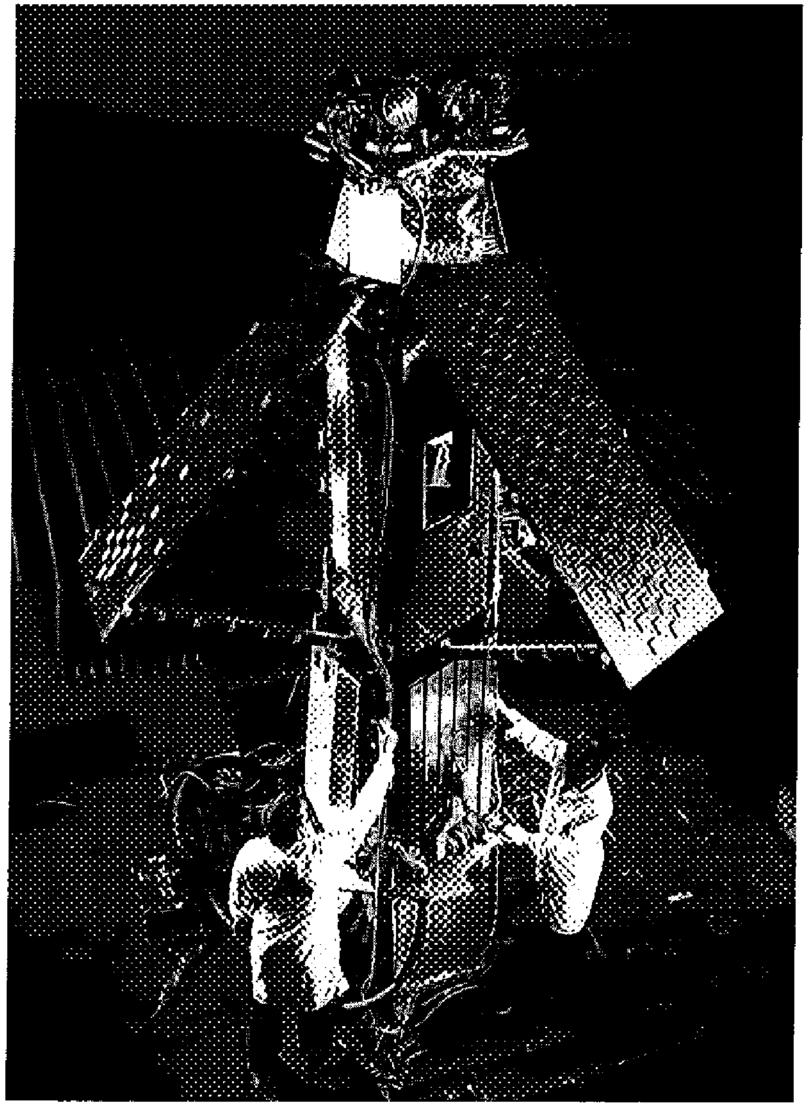
Image



Gravity Probe B

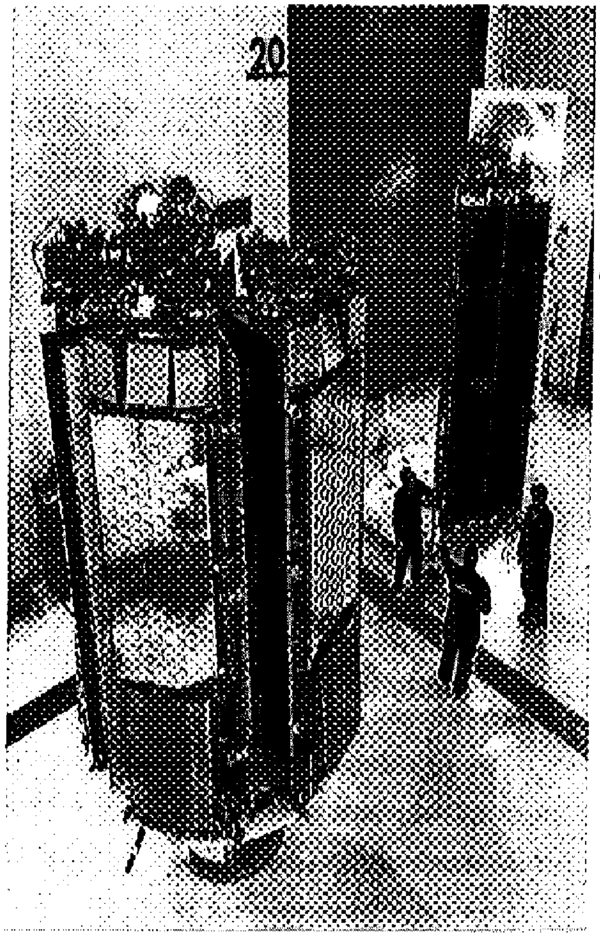
Provides Enhanced Instrument Accommodation

LM700™ Spacecraft Bus



The Iridium bus being prepared for test

LM700™—Standard Bus

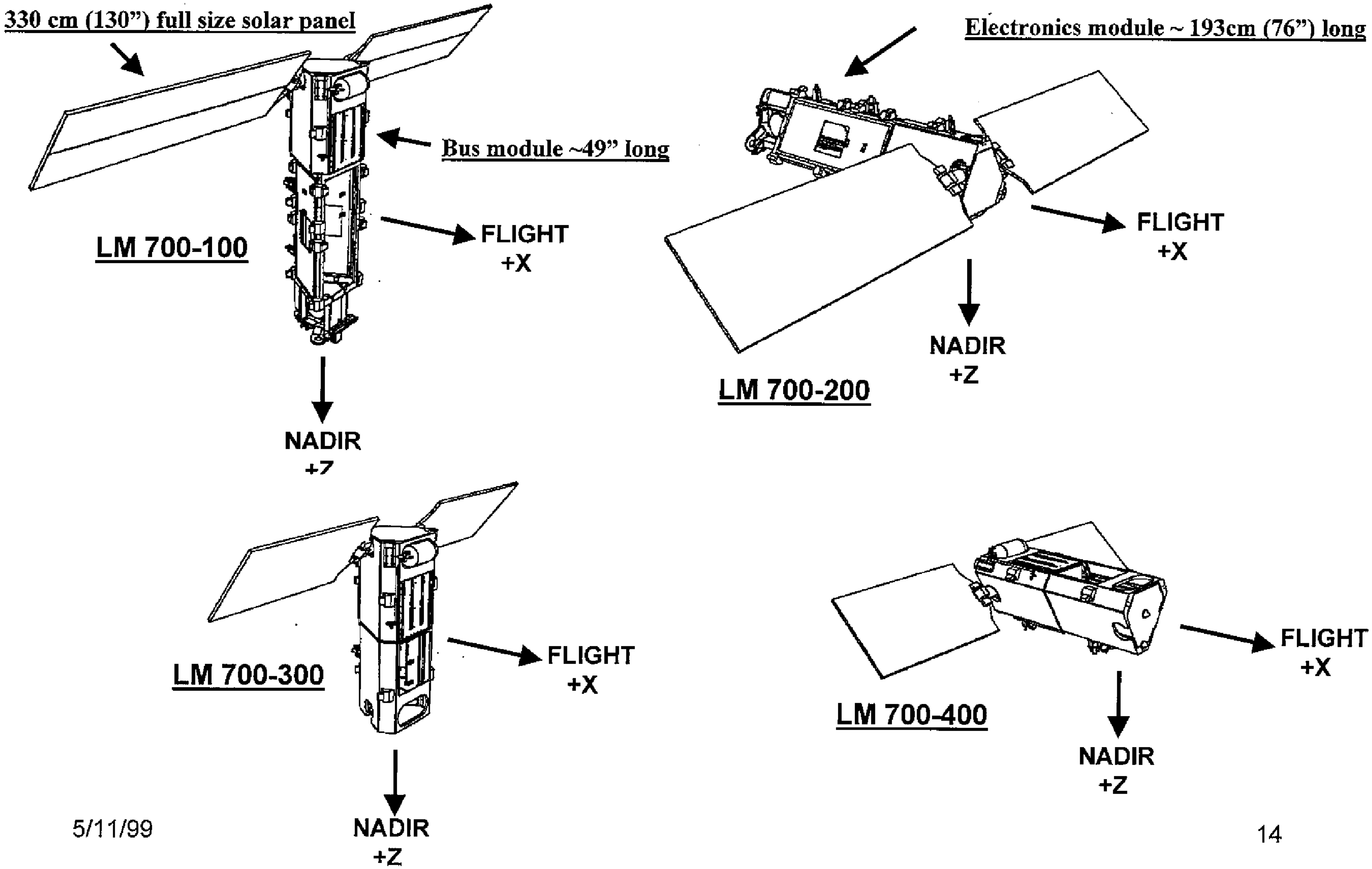


- Derived from IRIDIUM® production line
  - IRIDIUM® contract with Motorola for 125 buses
  - First launch July 1996
- LM700™ features
  - Gr Ep structure—bus/electronics sections
  - Propulsion
    - Hydrazine reaction engine assembly thrusters for attitude control and back-up for orbit adjust
    - High Isp electro-hydrazine thruster (EHT) for orbit adjust
  - Attitude control system
    - Momentum bias
    - Three-axis gyro (TGA)—ring laser
    - Horizon sensors
    - Magnetic torque rods
    - Magnetometers
    - Reaction wheel
  - Electrical Power System
    - 1200 W solar array (EOL)
    - Single 50AH NiH_2 battery

LM700™ Options

- LM700™ options
  - Shortened structure (2 bus modules)
  - Lengthwise orientation along velocity vector
  - Shortened solar arrays—60% and 80% power for Athena-1 234 cm (92") shroud packaging (approx. 200 or 350 watts for payload - 500 W for full arrays)
  - Flight software modifications
  - Comm subsystems - SGLS or STDN

LM700™ On-Orbit Configurations



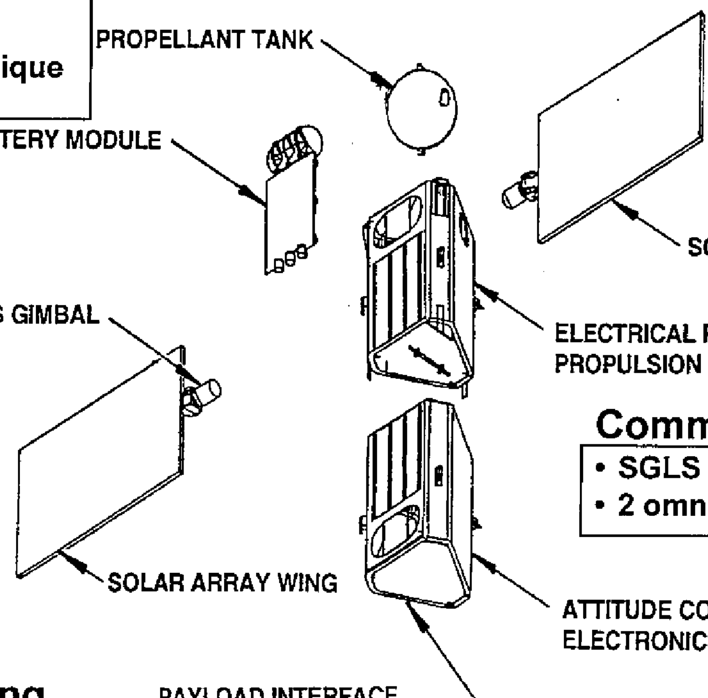
LM700™ Bus Capability

Structures

- Graphite epoxy composite frame
- Aluminum honeycomb core with graphite epoxy face sheets and shelving
- Modified mounting brackets and unique payload adapter

Attitude/orbit control

- 3-axis momentum bias control
- 7-0.2 lbf REA thrusters
- 1-0.08 lbf EHT thruster
- Hydrazine propellant/tank
- ΔV_{tot} = 675 m/s



Electrical power

- 50 Ah (rechargeable) NiH_2 battery
- 2 deployable GaAs solar panels 960W (EOL) (80% arrays)
- 28V unregulated electrical bus

Communications options

- SGLS or STDN uplink/downlink
- 2 omni antennas

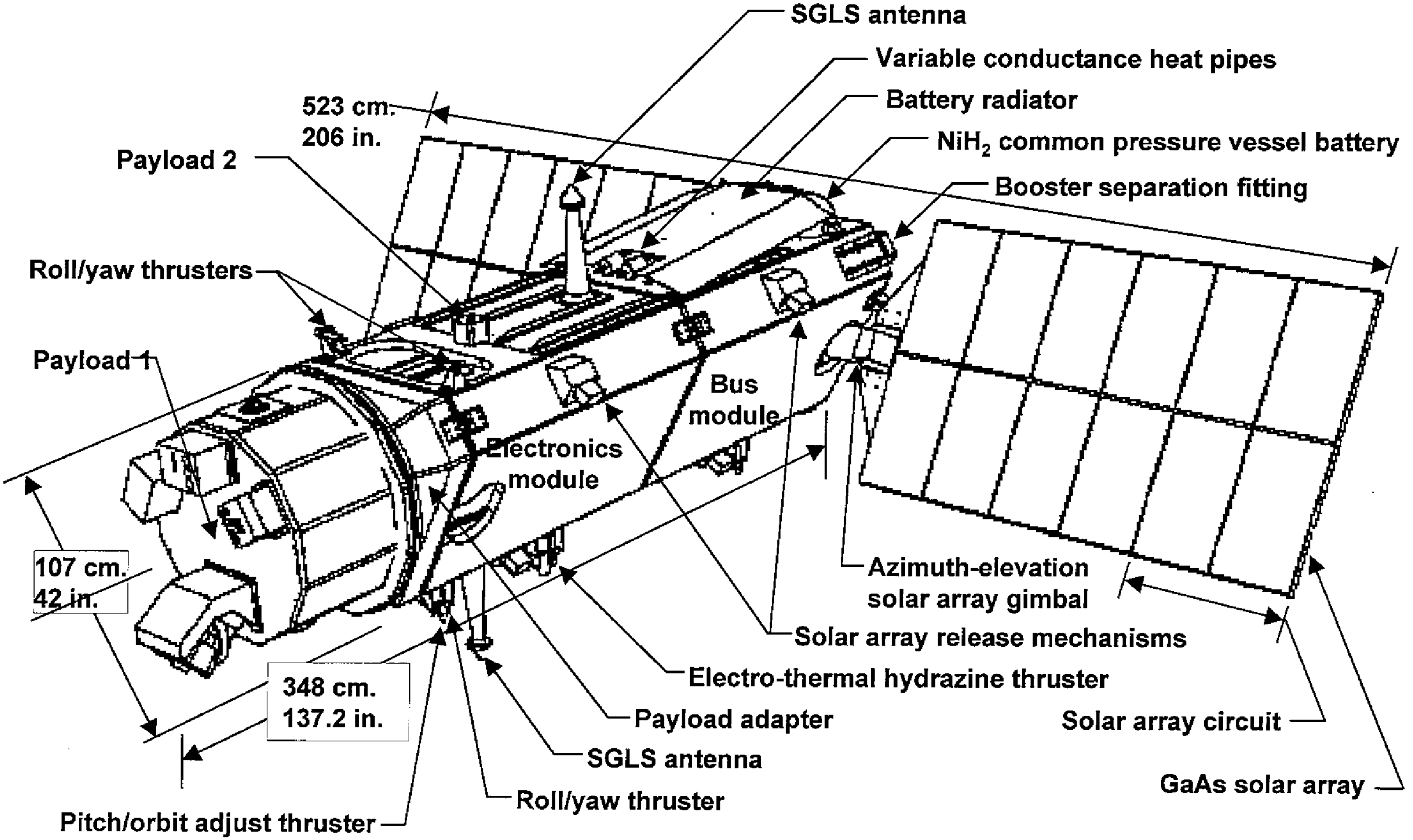
Command and data handling

- 12 MIPS R3000 flight computer
- Realtime and stored commands and telemetry
- Discrete, analog and 1553 payload IFs
- SEAKR 64 Mbyte solid state recorder

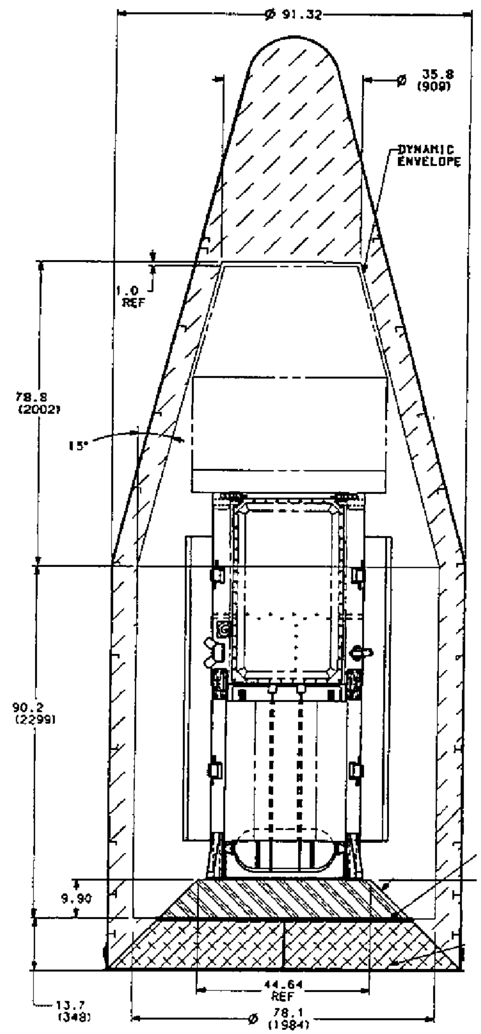
Thermal control

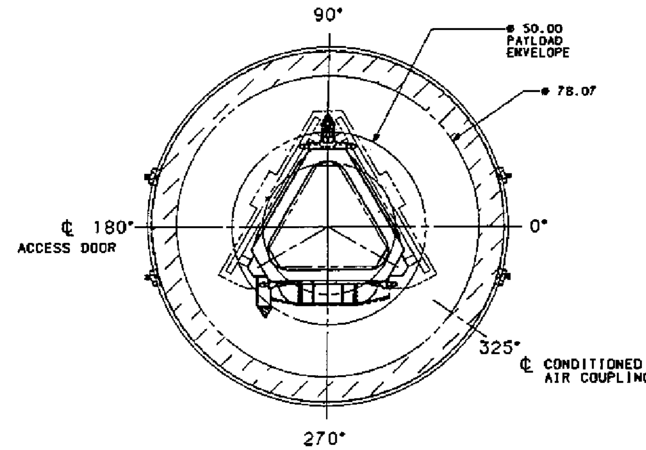
- Computer-controlled heaters (resistive)
- Passive thermal coatings, finishes, and MLI
- Battery radiator with feedback controlled variable conduction heat pipes

Sample LM700™ Configuration



LM700™ - 300/400 on Athena-1



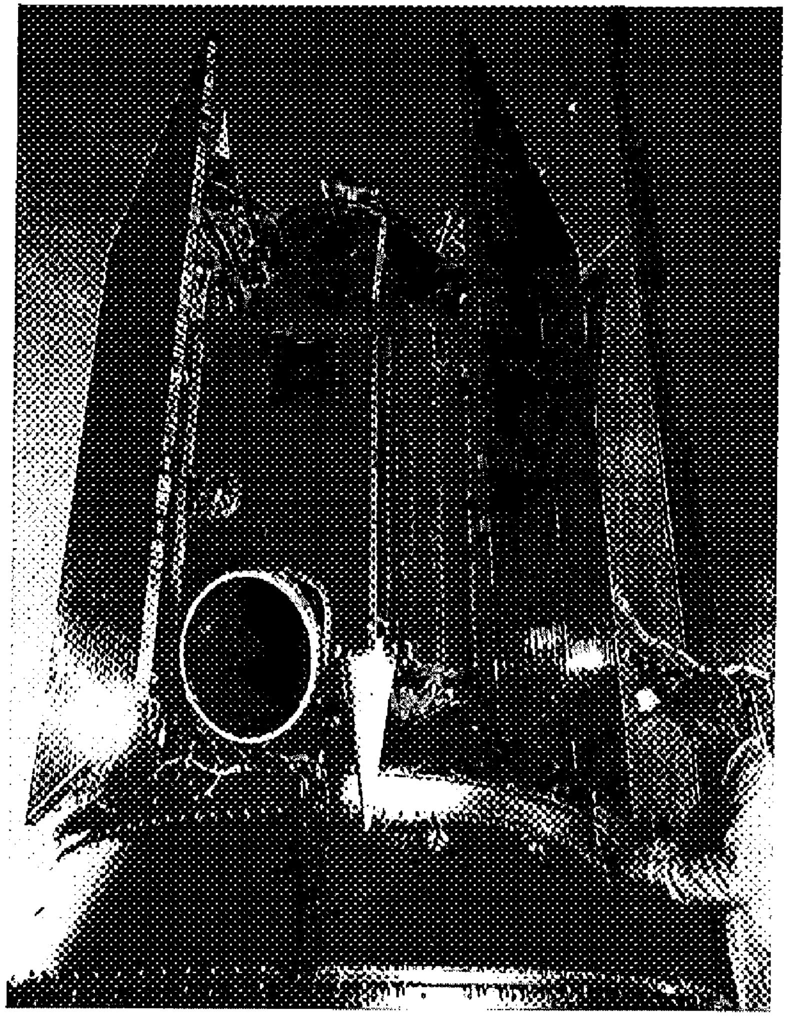


- 230 kg. (500 lb) nominal payload to 650 km @ 28.5° inclination
- Payload Volume: 6000 cu. cm. (57 cu. Ft.) external
  1200 cu. cm. (11 cu. Ft.) internal
- Basis:
  640 kg (1400 lb.) Total spacecraft weight (wet)
  410 kg (900 lb.) LM700™ bus includes 250 lb. of propellant
- Nadir Payload Sensor Volume: 100cm D x 89cm L
- Pallet Payload Sensor Volume: 165cm L x 66cm W x 46cm H
- Internal Payload Volume: 160cm L x 48cm W x 28cm H

LM700™ Launch Vehicle Limits on Payload

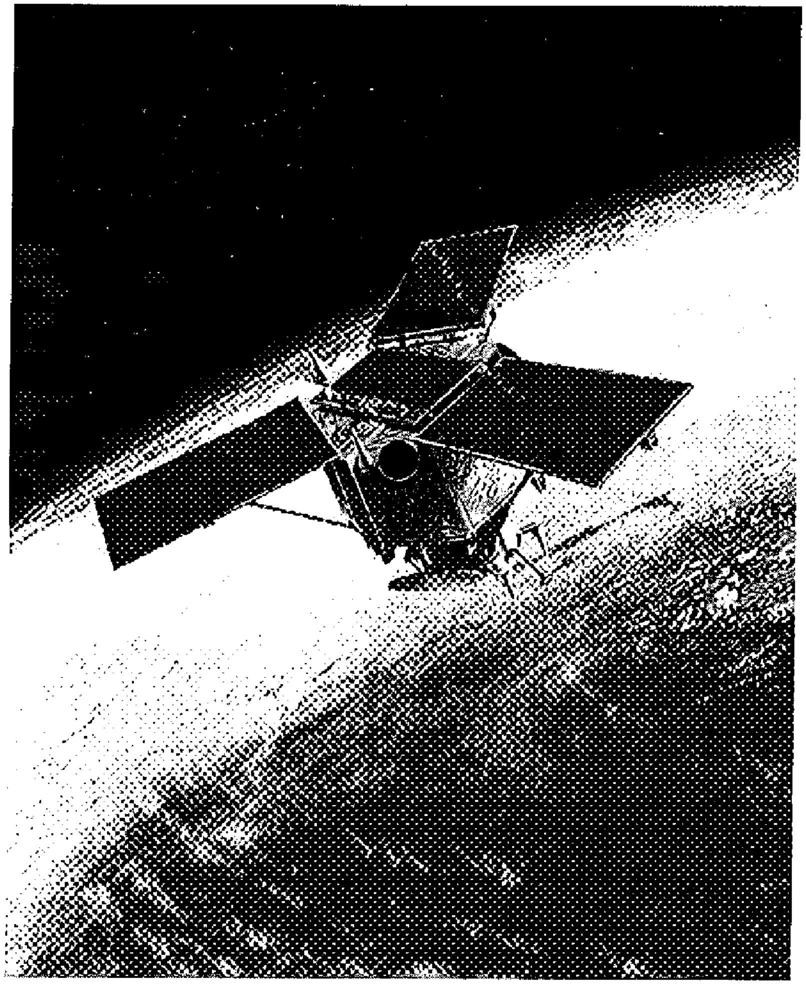
- Athena-1
  - Most efficient operation - Boost to 100nmi and use LM700™ EHT to reach final orbit
  - Approximate limits for 500 km orbit
    - 57 deg. ~ 230 kg (500 lbs)
    - 70 deg. ~ 180 kg (400 lbs)
    - Sun synch. ~ 70kg (150 lbs.)
- Athena-2
  - Limit is LM700™ structure capability ~230 kg (500 lbs.)

LM900™ Spacecraft Bus



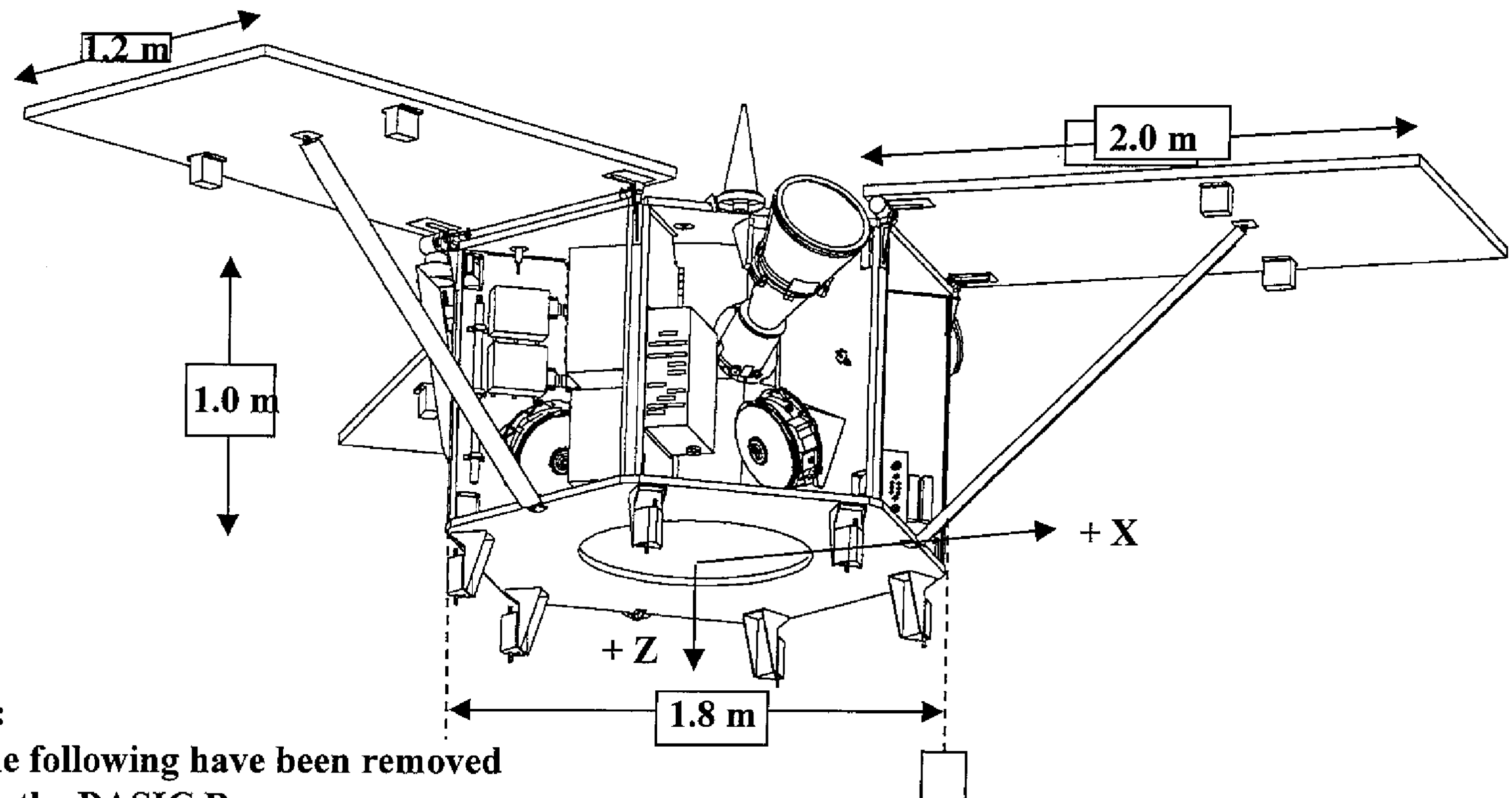
The CRSS (Ikonos) bus being prepared for test.

CRSS® Heritage of LM900™



- Customer:
  - Space Imaging Inc.
- Operation:
  - Agile spacecraft to image arbitrary earth locations
  - Images collected by precision scan of linear array
- Lockheed Martin Role:
  - Prime contractor and system integrator
  - Space, ground and launch segment

LM900™ Basic Spacecraft Bus Description



Notes:

(1) The following have been removed for the BASIC Bus:
- Imaging Sensor
- Imaging Sensor Outer Barrel
- Wideband Downlink and Gimbal

(2) Bay Covers removed to show interior equipment

LM900™ Design Features

- Commercial Remote Sensing Satellite (CRSS)
- Mission Life: 6 yrs, MMD 5 yr
- Aluminum Hexagon Structure
- Mass: 500 kg (1100 lbs)
- Reliability: > 0.9 reliability at 5 years

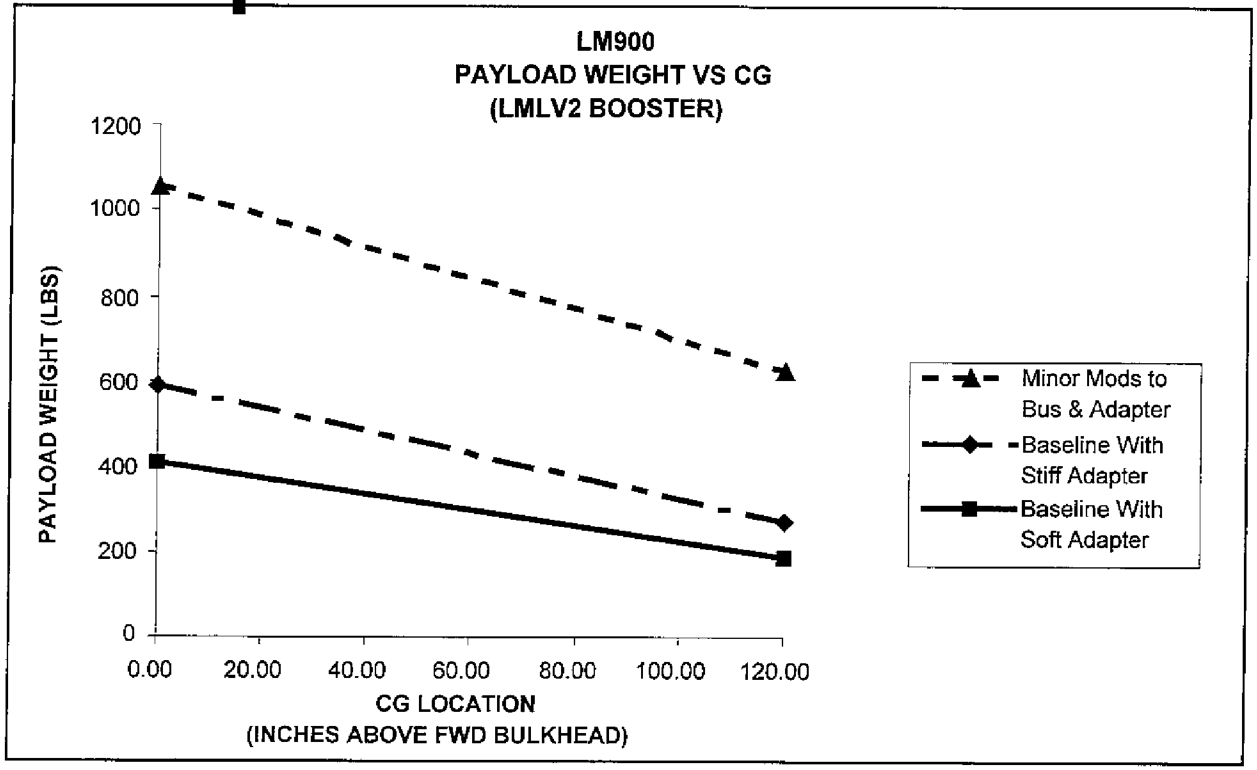
- Propulsion:
  - Six Thrusters, 0.2 lbs each
  - Monopropellant: 83 lbm(N_2H_4)
  - Total Impulse: 16,700 lbf-sec
- Power
  - Battery Ni H_2: 50 Amp-hrs
  - Unregulated Bus Voltage: 28±6 Vdc
- Thermal Control
  - Battery radiators
  - Conduction cooled

- Zero Momentum, 3-Axis Stabilized
- Agility
  - 4 deg/sec max rate
  - 0.2 deg/sec acceleration
- Precision Attitude Determination & Pointing
  - Pointing Control ± 12 arcsec (1sig)
  - Pointing Knowledge ± 10 arcsec (1 sig)
- Pointing Stability
  - 2.5 arcsec (< 1 Hz)
  - 0.8 arcsec (> 10 Hz)

LM-900™ Baseline Payload Capabilities

- Payload Mass
  - up to 500 kg
- Payload Volume
  - Internal Cylinder Vol: 78 cm dia x 101 cm
  - External Volume: 220 cm dia x 127 cm
  - Electronics Bay: 94cm x 84cm x 38cm
- Power
  - Solar Arrays: 3 Fixed
1200W BOL/ 1022W EOL peak
power to payload orbit dependent
- Wideband Communications
  - S-Band @ 2 Kbps uplink
  - X-Band @ 32 Kbps downlink
  - CRSS Gimballed Antenna, X- Band @ 320 Mbits/sec downlink
- Solid State Recorder
  - up to 80 Gbit (BOL) EDAC
  - protected high-speed memory

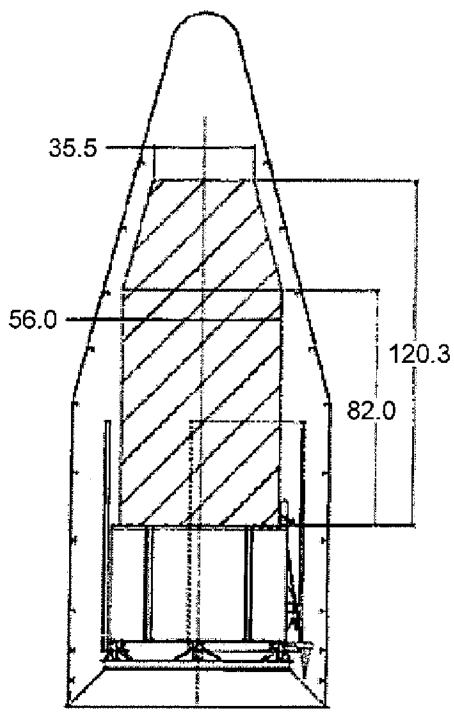
LM900™ Increased Payload Mass Capabilities



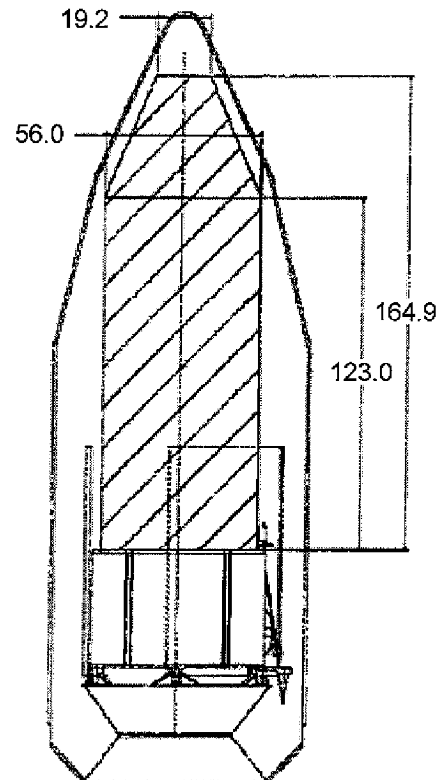
An increased payload load capability is available on a mission-unique basis with minor booster adapter and bus modifications. For all payloads, a complete dynamics analysis of the integrated spacecraft must be completed to ensure compatibility of all components.

(The above is based on a quasi-static analysis of LM900™ on Athena-2 booster)

LM900™ Payload External Envelopes



92 in LMLV-2



92 in Taurus
Orion 38 Configuration

Conclusion

- **LMMS offers range of smallsat busses**

ORBITING TECHNOLOGY TESTBED INITIATIVE (OTTI)

PROGRAM PRESENTATION

TO: RideShare Conference

JIM RITTER

SAIC

ART CAMPBELL

NRL

APRIL 15, 1999

THE NASA SPACE CHALLENGE:

n An Order of Magnitude Increase in Performance

n Significantly Lower Power Devices and Systems

n Lower Weight Spacecraft and Launch Vehicles

n Lower Cost Devices and Spacecraft

n Faster and Cheaper Assembly Times

n Reliable Systems Capable of Operation Anywhere
in the Natural Space Environment

Faster, Cheaper and Better Space Systems!

THE COMMERCIAL SPACE CHALLENGE:

(The Goal of World-wide Voice, Data, Fax, Surveillance and Video Teleconferencing Requires:

- Large Numbers of Spacecraft for Coverage
- Higher Orbits Permit Use of Fewer Spacecraft, but Require Hardening
- Large Investments in Both Space and Ground Systems

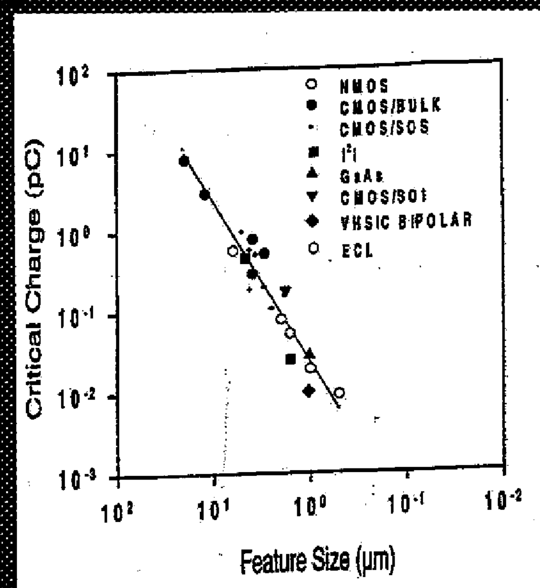
(International Competition Requires:

- State-of-the-art Technology
- Fast Time to Orbit, Mass-produced Spacecraft
- Reliable Systems Capable of Operation in the Natural Space Environment

Faster, Cheaper and Better Space Systems!

HIGH PERFORMANCE COMMERCIAL DEVICES ARE OFTEN VERY SENSITIVE TO NATURAL SPACE RADIATION

- Device Vulnerability to SEE and Total Dose Increases as:
  - Feature Size Decreases (Capability Increases)
  - Speed Increases
  - Voltage and Power Decrease
- New Technologies Must Be Space Qualified Before Use in Operating Systems



HOW CAN NASA MEET THESE GOALS?

(Use Novel, Break Through Technologies
  - X 5-10 Increase in Performance
  - Potential New Capabilities

(Use COTS or Rad Tolerant COTS Parts Rather than Rad Hard Parts
  - X 10 More Capable (2-3 Generations Ahead of Rad Hard)
  - Less Expensive, More Available

(Partner With and Leverage Commercial Space and Industry
  - Fly Technologies of Interest to COMSATS
  - Industry Pays for Its Payloads
  - Make Use of Commercial Spacecraft and Launch Vehicles to Further Reduce NASA's Costs

THE OTTI PROGRAM WILL:

(Demonstrate and Space Qualify Break Through Technologies and COTS Systems

(Partner With the Commercial Satellite Industry, Fly Their Payloads and Use Their Spacecraft and Launch Vehicles, If Possible

(Operate in a GTO or MEO High Radiation Orbit

(Compare Ground Tests to Space Tests

(Develop New Models With Reduced Uncertainty (Lower Safety Factors Required= Reduced System Costs)

PURPOSE - SUMMARY

- PURPOSE: OTTI Is a Program to: (1) Explore Novel, Emerging Breakthrough Technologies and Advanced SOA Devices and Adaptive Subsystems With Substantial Potential Impact on Space System Performance and to: (2) Decrease the Time and Cost Required for Insertion Into Future NASA Systems by Space Demonstrations and by Leveraging Commercial Space Systems

- SUMMARY:
  - Explore, Assess and Test Potential Breakthru Technologies
  - Select Most Promising Technologies and Plan Space Expt.
  - Construct Payloads and/or Spacecraft
  - Predict Space Performance Using Best Models, Ground Tests
  - Launch Experiment and Analyze Space Data
  - Compare Space Data to Predictions and Develop New Models
  - Leverage Commercial Space Systems to Reduce Costs

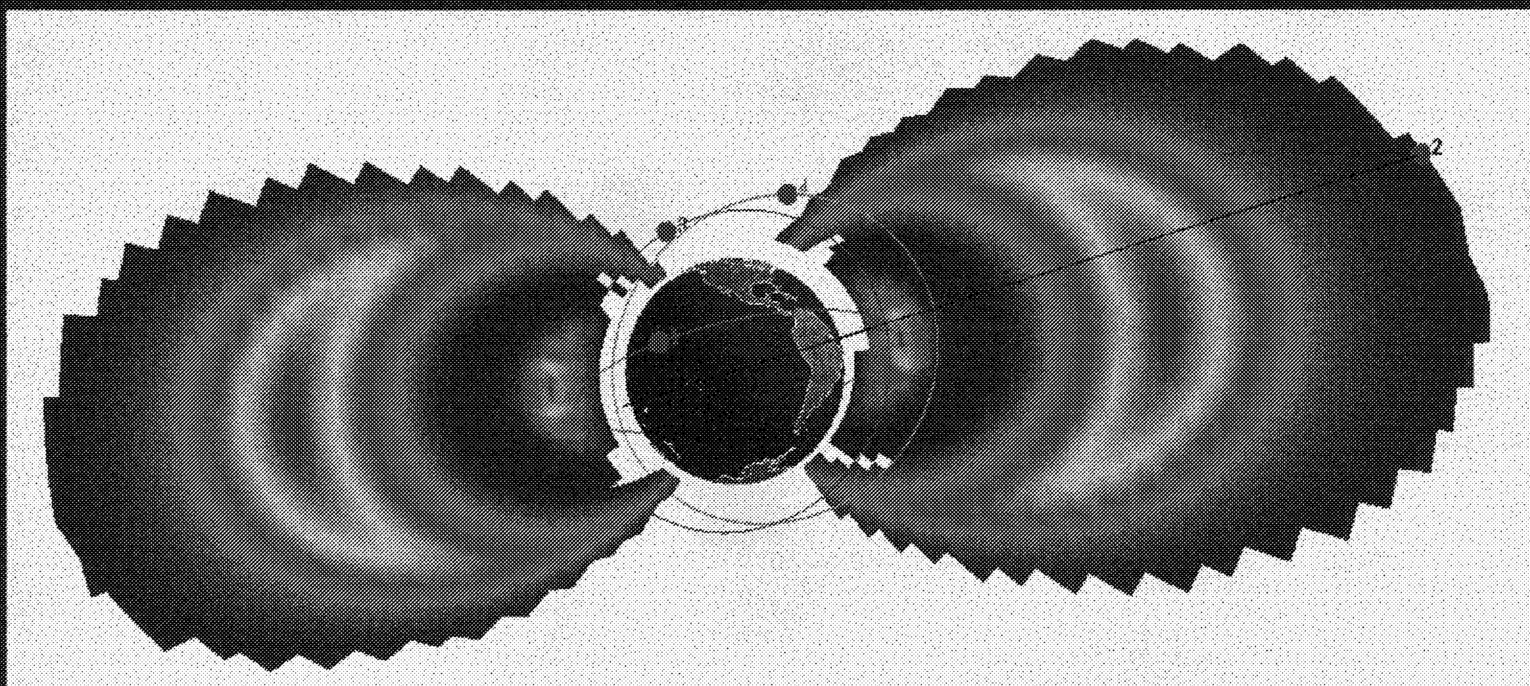
THE OTTI TEAM:

- ä NASA HQ
- ä NASA GSFC
- ä JPL
- ä NASA MSFC
- ä NASA GRC
- ä NASA LaRC
- ä NASA JSC
- ä SAIC
- ä NRL
- ä AFRL
- ä DSWA
- ä UNM
- ä SANDIA

ORBITS CONSIDERED FOR OTTI

1. Circular MEO, Equatorial 3,000 km
2. GTO, 360 X 36,000 km, 18 Degrees
3. Circular MEO, Polar, 3,000 km
4. Elliptical MEO, Polar, 1,000 X 6,000 km

GTO Recommended for Maximum Coverage of Radiation Issues



INITIAL EXPERIMENT LIST

Devices

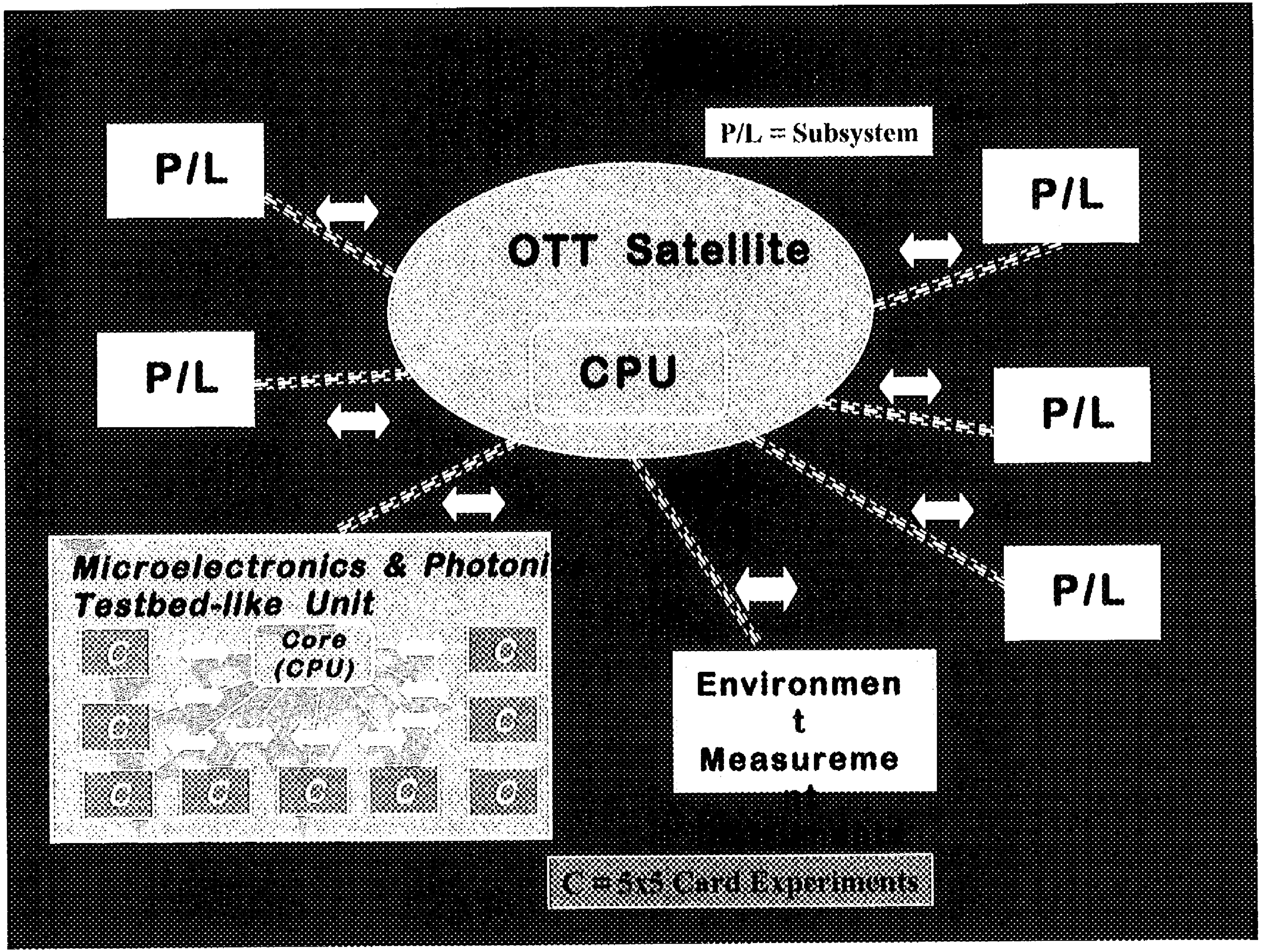
1. Low Power CMOS (0.3 V)
2. Magnetic Thin Film Non-volatile Memories
3. Advanced Cots Devices
4. LT GaAs Devices
5. InP Devices
6. SiGe Devices
7. InAs Devices
8. Vertical Cavity Surface Emitting Lasers
9. Reconfigurable Processing
10. COTS In Multichip Module Packaging
11. Solar Cell Experiments
12. MEMs
13. Erasable Hard Disc Memory

Subsystems

14. IR, UV and Visible Sensors
15. P-channel CCDs and CMOS Active Pixel Image Sensors
16. 32 Gbps VCSEL Based Optical Bus
17. Fiber Optic Data Bus
18. Star Tracker, Sun and Earth Sensors
19. Artificial. Neural Nets
20. Fuzzy Logic Circuits
21. System on a Chip
22. GPS Receiver
23. Direct Intra-board IR Communication

Environmental Instruments

24. Proton Spectrometer
25. Dosimeters
26. Credo III Or IV
27. Cease


P/L = Subsystem
OTT Satellite
CPU
P/L
P/L
P/L
P/L
P/L
Environmen
t
Measureme
Microelectronics & Photoni
Testbed-like Unit
Core
(CPU)
C
C
C
C
C
C
C
C
C
C = 5x5 Card Experiments

POTENTIAL LAUNCH PARTNERSHIPS* (Commercial Communications Satellite Industry)

Launch, Spacecraft Acquisition Possibilities

- Orbital Science - CEO
  - Up to 50kg, 200 W (Max.) Payload on Each Satellite (12)
  - 1965 km, 0 Degrees
- DRG - LEO 1
  - Up to 120 Lb., 100 W Payload
  - 950 km, 50 Degrees or 950-4000 km, 50 Degrees, Elliptical
  - 165 kg, 200 W Satellite
- Motorola - Iridium (INX)
- Teledesic - 1400 km
- Lockheed Martin
- Spectrum Astro
  - SA 200B Bus, 3 Axis Stabilized, Available on IDIQ

* In Exploratory Stage

PAYOFFS: - OTTI WILL PROVIDE PATTERN FOR NASA AND COMMERCIAL COMMUNICATION SATELLITE INDUSTRY PARTNERSHIP

- NASA Could Take Advantage of Industry's Mass Produced Spacecraft and Frequent Launches by Using the OTTI Example, Modifying Commercial Space Hardware and Launching Jointly
- Industry Could Launch NASA Payloads on Its Satellites With Cost Sharing
- NASA Could Launch Industry Payloads on Its Testbed With Cost Sharing

OTTI PAYLOAD*

(High radiation orbit required - elliptical GTO or MEO
- Elliptical GTO preferred for radiation variety
  - ¶ trapped electrons and protons as well as cosmic ray ions and solar event particles are important to experiment
- MEO in proton belts acceptable <1400 km

(Weight - 75 kg

(Size - 100x80x30.5 cm (expect multi-package, auxiliary experiments)

(Power - 150 watts (can easily power share but must maintain biases)

* **In Exploratory Stage**

FINAL ANALYSIS

Quick Ride: An Innovative Approach For Low Cost, Quick Access Small Payload Missions

RideShare Conference

April 15, 1999

9701-E Philadelphia Court - Lanham, Maryland 20706-4400 301-459-4100 - www.FinalAnalysis.com

FINAL ANALYSIS

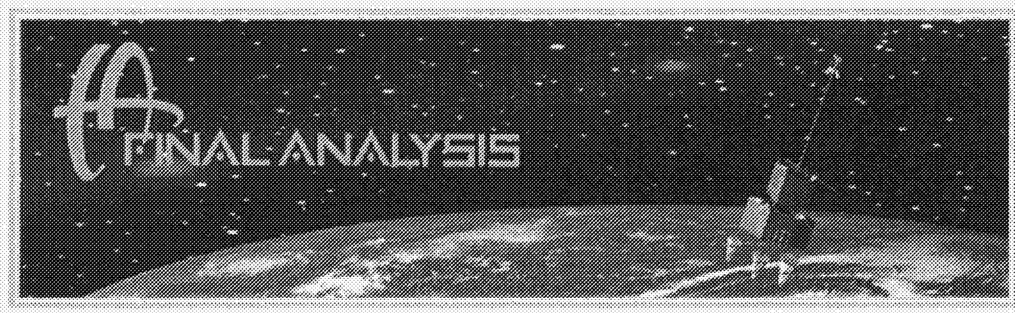
Contents

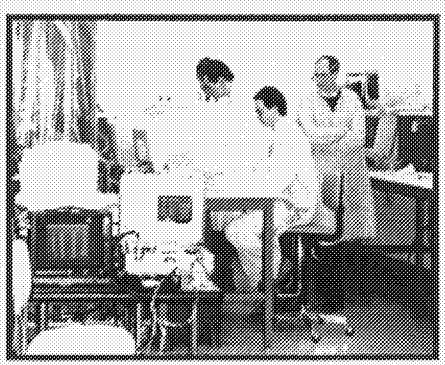
- Background
- Flight Opportunities
- Range of Accommodations
- Optional Services
- Program Plan
- Cost Summary
- Summary

FINAL ANALYSIS

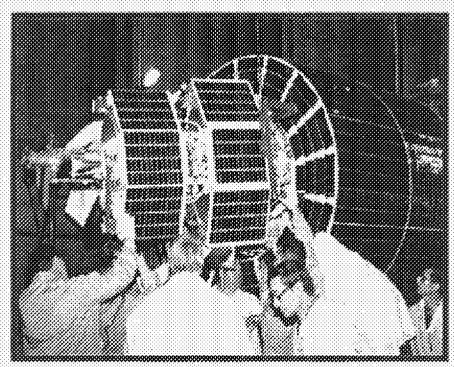
Background

A Privately-Owned Commercial Space Company Since 1992

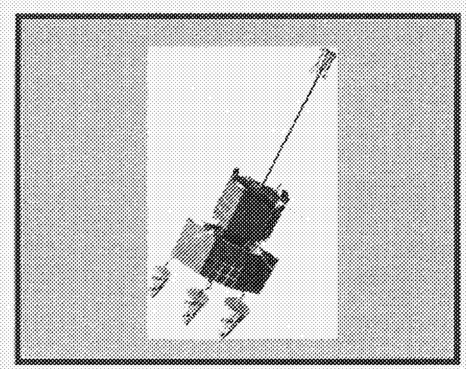




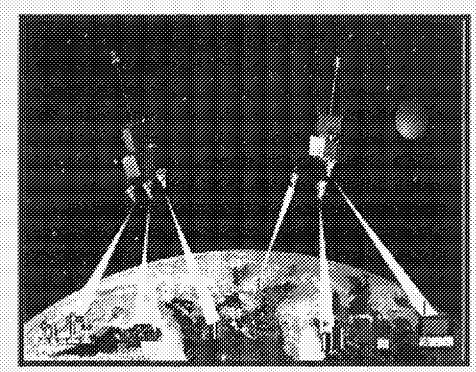
Aerospace Engineering Services



SatSystems Development



Secondary Payload Program



Mobile Satellite Systems

FINAL ANALYSIS

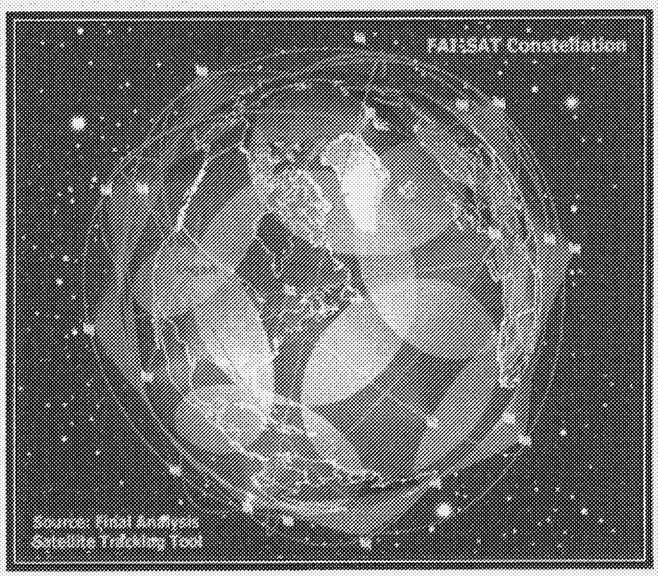
Background

- 4-5 year history of promoting secondary payloads
- Incorporated payload accommodation in satellite design
- Responded to NASA's QUICK RIDE announcement
- QUICK RIDE provides:
  - Launch
  - Satellite control center (Lanham, Maryland)
  - Operations
  - Payload data available via dedicated line/web

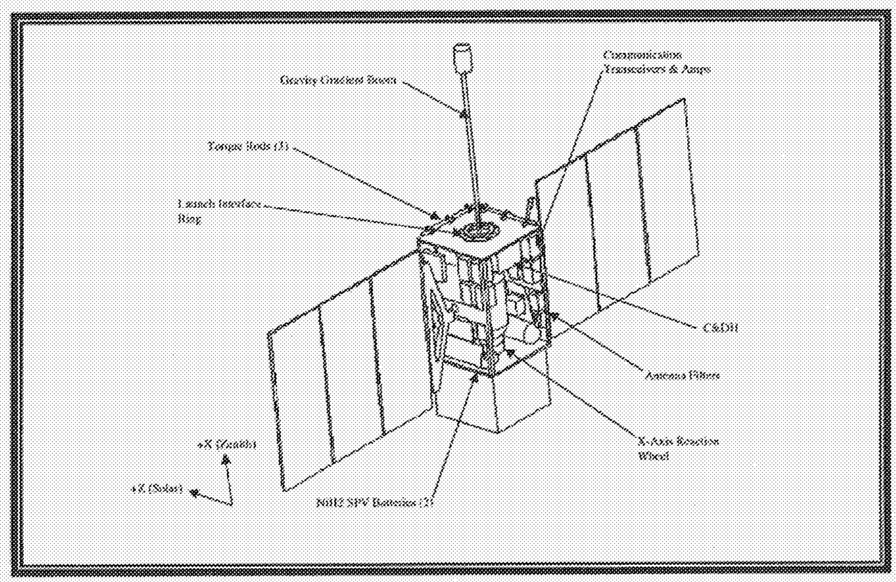
FINAL ANALYSIS

Constellation & Satellite

Constellation



Satellite



Manifest

Contract Line Number					
Planned Manifest Date:	9/01	3/02	9/02	3/03	9/03
Number of Rides on Manifest Date:**	6	6	6	6	8

**All missions will have an orbit altitude of 1000km, an orbit inclination of either 51° or 66°, and an eccentricity of 0.0 ± 0.01.

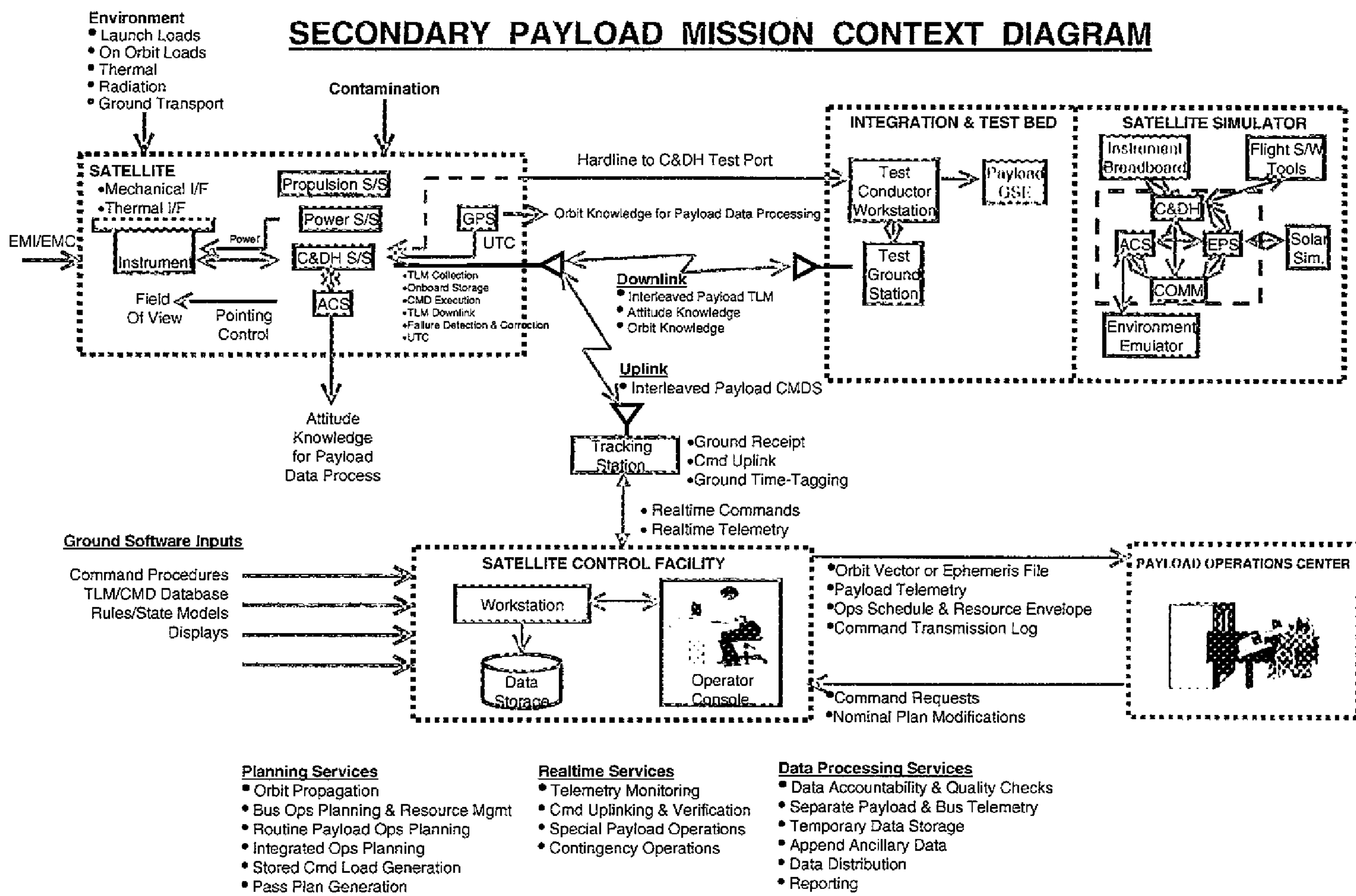
FINAL ANALYSIS

Accommodations Summary

Performance Characteristic	Quick Ride Minimum	Standard Service
Instrument Mass	10 Kg	$\leq$ 20 Kg
Instrument Power	10 watts	< 20 watts Cont.
Instrument Volume	50,000 cc	$\leq$ 100,000 cc
Thermal Control	Isolated	Isolated
Data Storage	100 Mbits	$\leq$ 128 Mbits
Downlink Data	2 Mbits/day	4 Mbits/day
Data Rate (onboard)	1 Kb/sec	$\geq$19.2 Kb/sec
Command Uplink	200 bits/sec	$\geq$9.6 Kb/sec
Ordering Period	Prior to L-18 months	Prior to L-18 months
Instrument Delivery	L-9 months	L-9 to L-6 months
In-orbit Operations	12 months	12 months

FINAL ANALYSIS

Payload Mission Diagram



FINAL ANALYSIS

Optional Ground Software

- Additional telemetry points in database
- Additional commands in database
- Additional operations tools, rules, or other products, such as displays, procedures, or state models
- Adding ancillary data onboard
- Adding more complicated commanding or data collection pass scheduling requirements
- Additional ground processing of data collected

FINAL ANALYSIS

Program Plan

Phase	Description
1	1 Month Requirements Analysis to perform trade-offs to determine standard or optional services
2	3 Month Payload Interface Design, Operations Planing and I&T Planning leading to a Mission Design Review
3	6 Month Operations and Interface Development unique space and ground interfaces are built.
4	6 Month integration of payload into the satellite including environmental testing
5	2-3 Month launch schedule

FINAL ANALYSIS

Integration & Test

- Payload integration at Lanham, Maryland
- Controlled Access
- Clean Rooms (Class 10,000)
- Integration performed by Final Analysis technicians according to the Integration Plan
- All handling devices are calibrated
- Strict static discharge control procedures are followed
- Observation by experiment team member (s)

Note: USG will furnish instruments, Flight software and instrument I&T software

Cost Summary

Quick Ride Flights with 12 Months of Operations.

Flight Number	Price per Flt (FY 99 $)
1	$2.6 Million
2 through 10	$2.5 Million

Accommodation Studies

Flight Number	Price per Flt (FY 99 $)
1 through 10	$115K

Mission Unique Modification

Flight Number	Price per Flt (FY 99 $)
1 through 10 Additional Optional Capabilities of Quick Ride: • High Rate Downlink • 256 MB Onboard Storage • Improved Attitude Knowledge	Priced per Task Order

FINAL ANALYSIS

Summary

- Customer provides documentation, procedures, test results, drawings etc… to enable Final Analysis to perform analyses, develop the interface, integrate and test the satellite with the Quick Ride payload
- Quick Ride offers low cost access to space
- Program depends upon NASA and industry cooperation.

FAI is ready to cooperate to the fullest extent possible! → Mission Success

FINAL ANALYSIS

Prepared by:

Jason O'Neil

Business Development

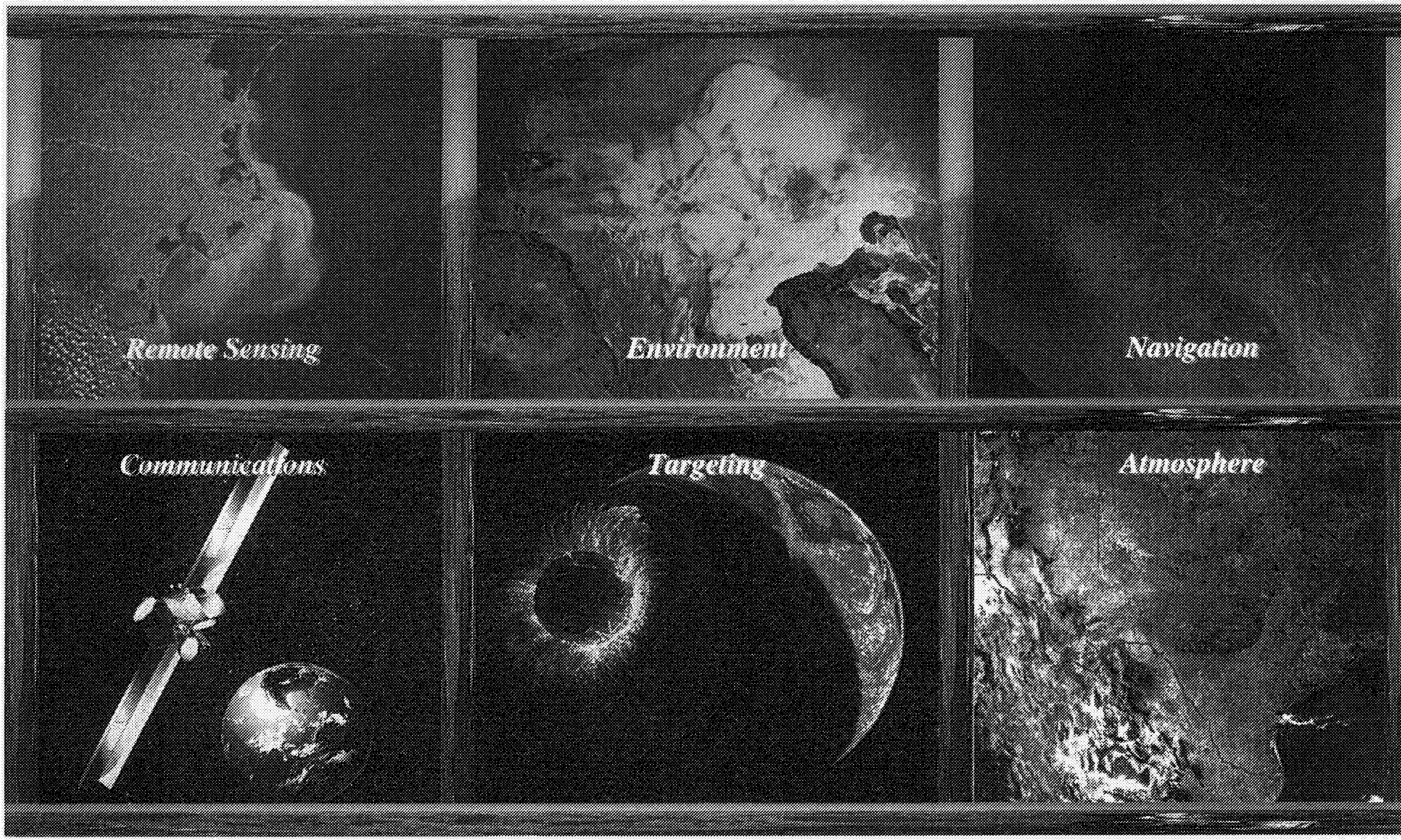
Final Analysis Inc.

9701-E Philadelphia Court

Lanham, Maryland 20706-4400

301-459-4100

jason@finalanalysis.com



The Office of Naval Research

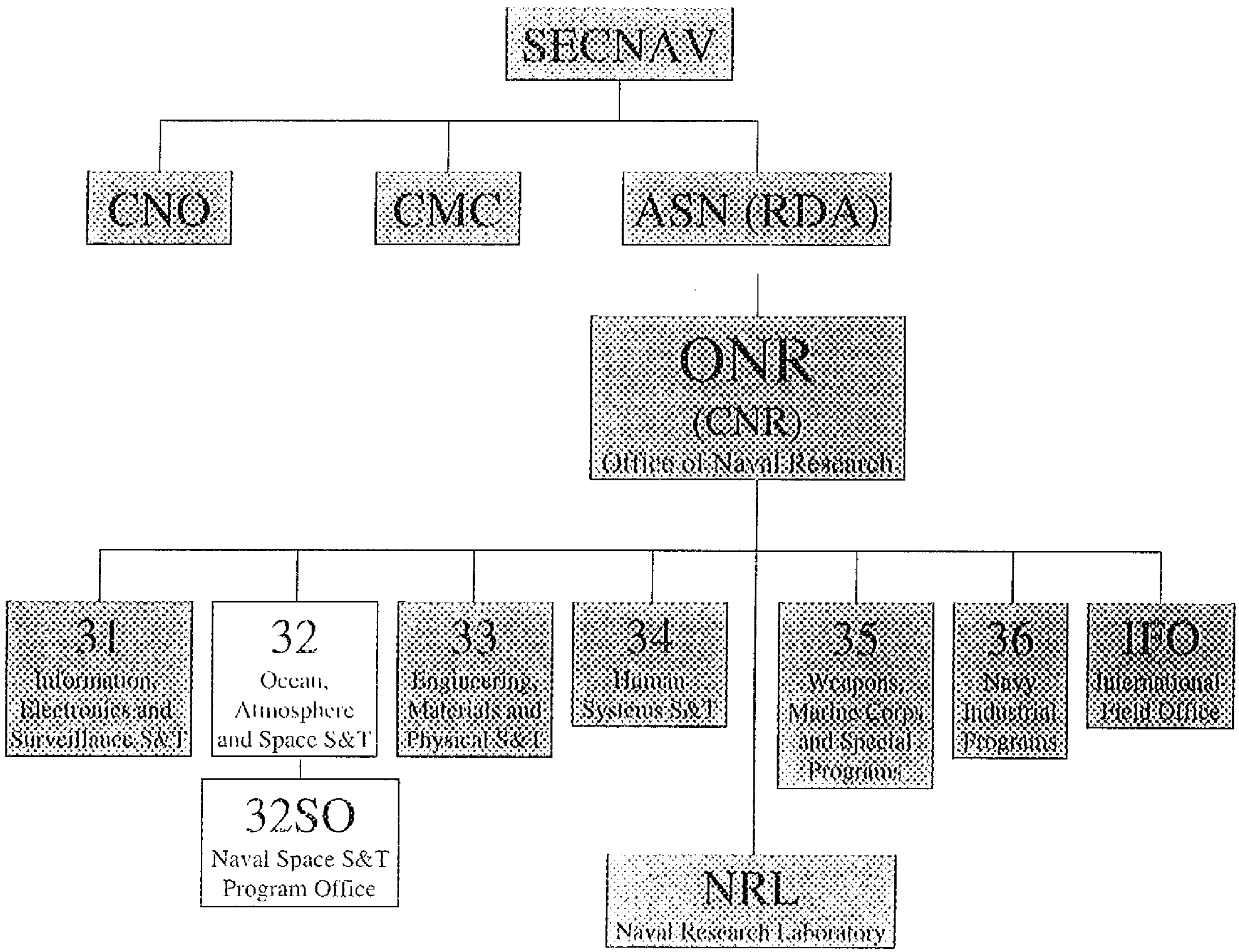
Ocean, Atmosphere, and Space S&T Department

The Naval Space S&T Program Office

Paul Regeon, 703-588-0702/regeonp@onr.navy.mil

- Naval Space S&T Program Office Overview
- Navy Payloads
- GEO Mission
- Enabling Technologies
- Summary

DON Organization Chart



Naval Space Science & Technology Program Office

RADM Gaffney (CNR) Chartered the Naval Space Science and Technology (S&T) Program Office.

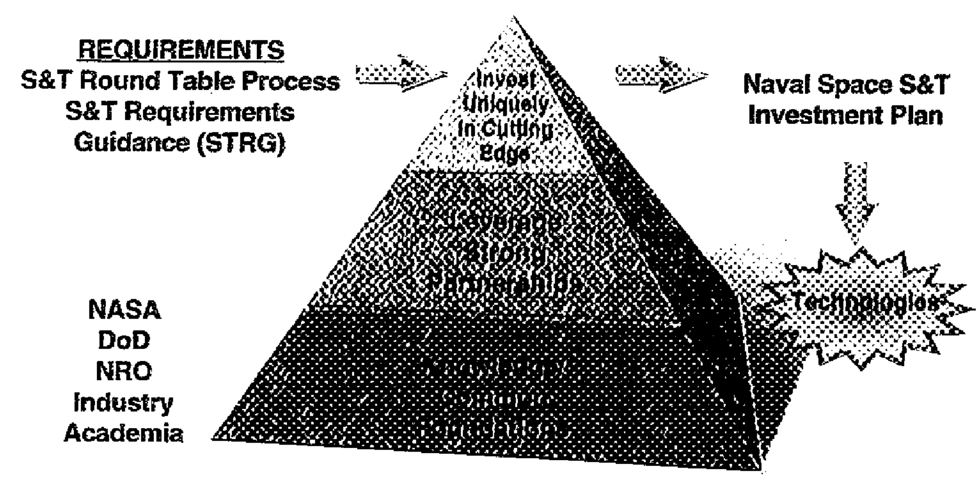
Focus:

- Central Point of Contact for DON S&T Activities
- Horizontal Linkage and S&T Transition With External Commands, PEO's, and Agencies
- Investment Strategy to Leverage DOD, Government and Commercial Initiatives
- ONR Program Officers Manage ONR Space Programs and Other DON Space Organizations Programs

Mission

Keep the Navy "*SMART*"

Support The Warfighter
Maximize Leverage of Navy Dollars
Acquire Partners
Rapid Technology Transition
Technological Superiority



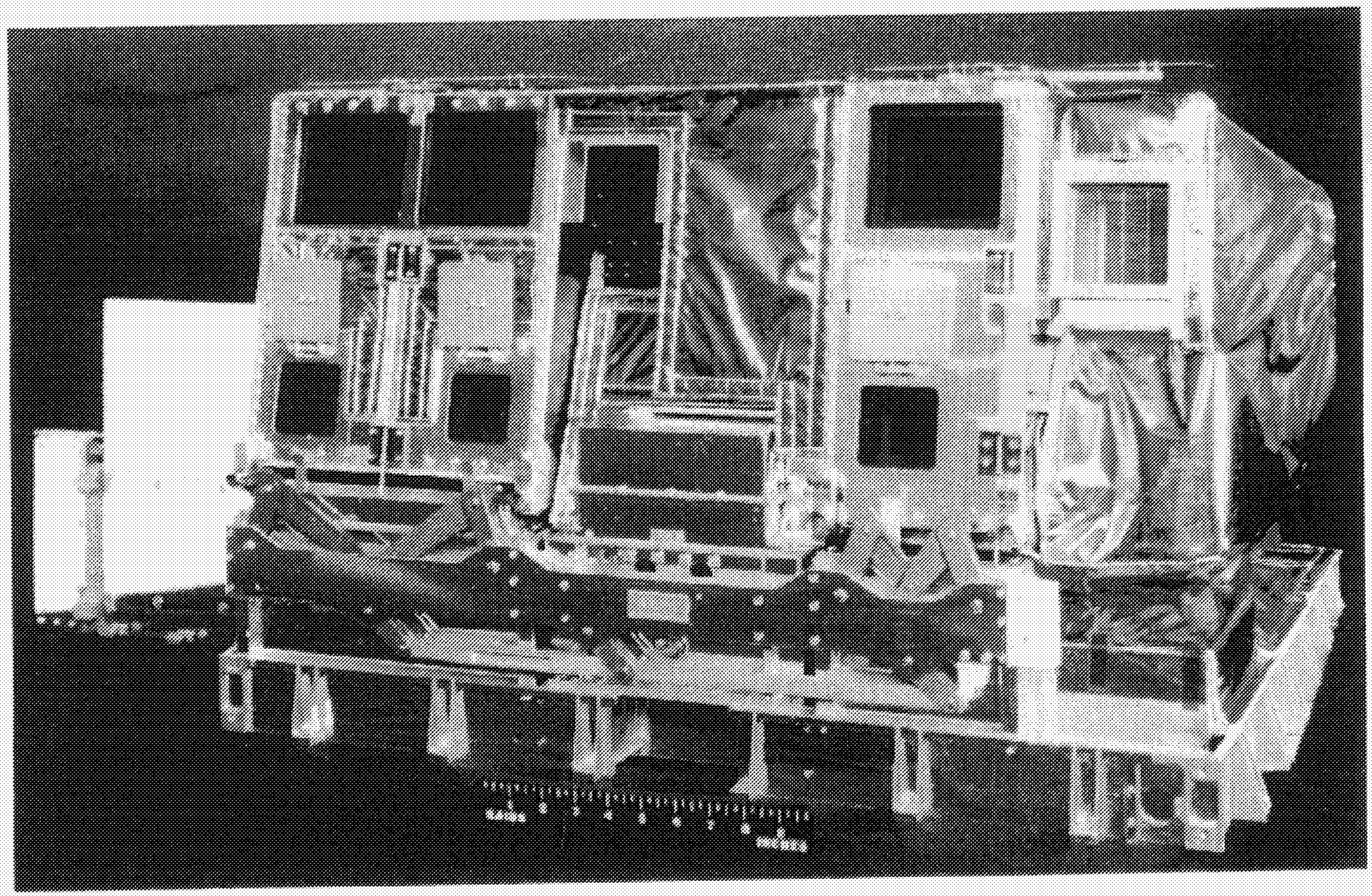
Naval Space S&T Program Investments

	FY98	FY99	FY00	FY01
Communication	Modulating Retro Reflector Geo Ionospheric Imager	GPS Anti-Jamming Geo Ionospheric Imager	GPS Anti-Jamming Geo Ionospheric Imager	Geo Ionospheric Imager
Navigation	Geo Ionospheric Imager Satellite Laser Ranging	GPS Anti-Jamming Geo Ionospheric Imager	GPS Anti-Jamming Geo Ionospheric Imager	Geo Ionospheric Imager
Environmental Sensing	WindSat NEMO HRST Aerosol Parameters Aerosols & Atmos. Parameters Wind Vector Modeling Active/Passive Microwave Freq. Polarimetric RS of Ocean Surface Passive Microwave Radiometry GEO Sensor Concept Study (SMI)	WindSat NEMO HRST Aerosol Parameters Aerosols & Atmos. Parameters ASIS Buoy Experiment GEO Bus Concept Study (SMI)	WindSat NEMO GEO Program Definition (SMI)	WindSat GEO Program Definition (SMI)
Surveillance	Sparse Apeture	Sparse Apeture		
Space Technology	IOBP	IOBP		

Technology Transition Path or Demos

	FY99	FY00	FY01
Modulating Retro Reflector	NRL 6.2 New Start	Base Program	Flight Demo
WindSat			Flight Demo
NEMO		Flight Demo	
Sparse Apeture		LEO Fizeau Demo Program (FY00-04) NRL/NRO	LEO Fizeau Demo Program (FY00-04) NRL/NRO
Geo Ionospheric Imager			Flight Opp. FY02
METOC GEO Program			METOC Start FY02
GPS A/J			Flight Demo

- Naval Space S&T Program Office Overview
- Navy Payloads
- GEO Mission
- Enabling Technologies
- Summary



Remote Atmospheric & Ionospheric Detection System (RAIDS)

8 Instruments (Spectrometers & Photometers)

Wavelength Coverage: 550 - 8700 Å @ 7-20 Å

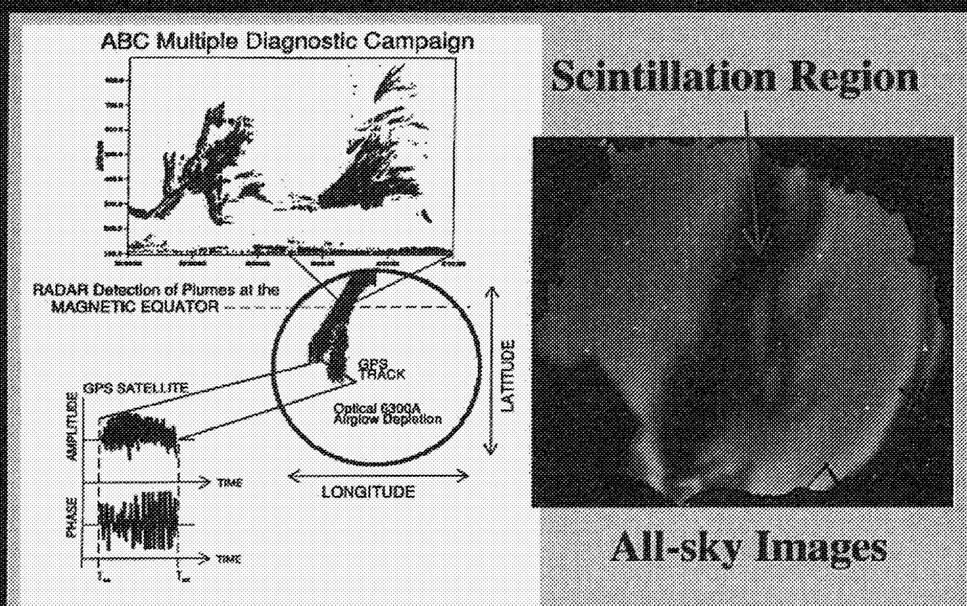
Scans the Limb: 50 - 750 km @ 5 km Resolution

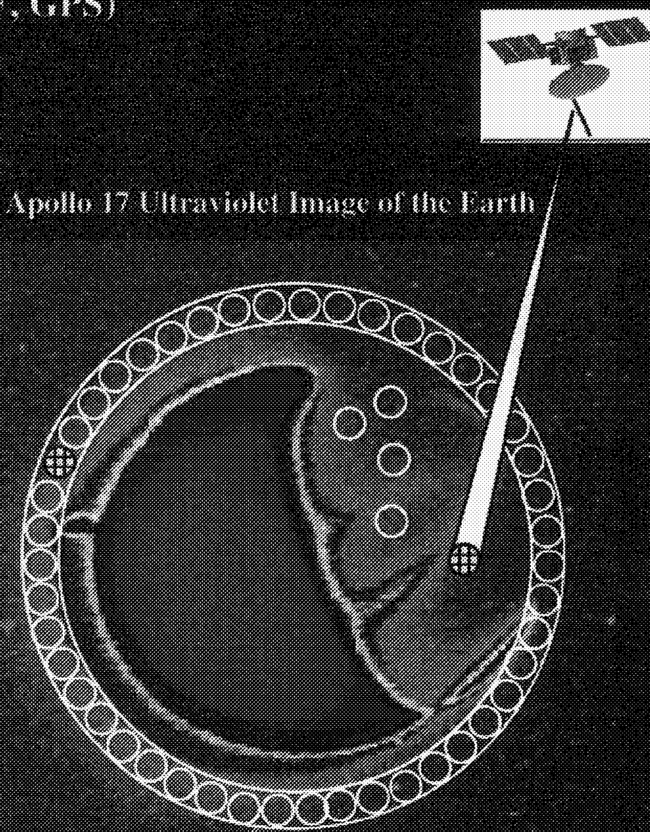
Expected Launch: 2001

Tactical Ionospheric Remote Sensing from Geostationary Orbit

Ionospheric Mapping & Geocoronal Experiment (IMAGE)

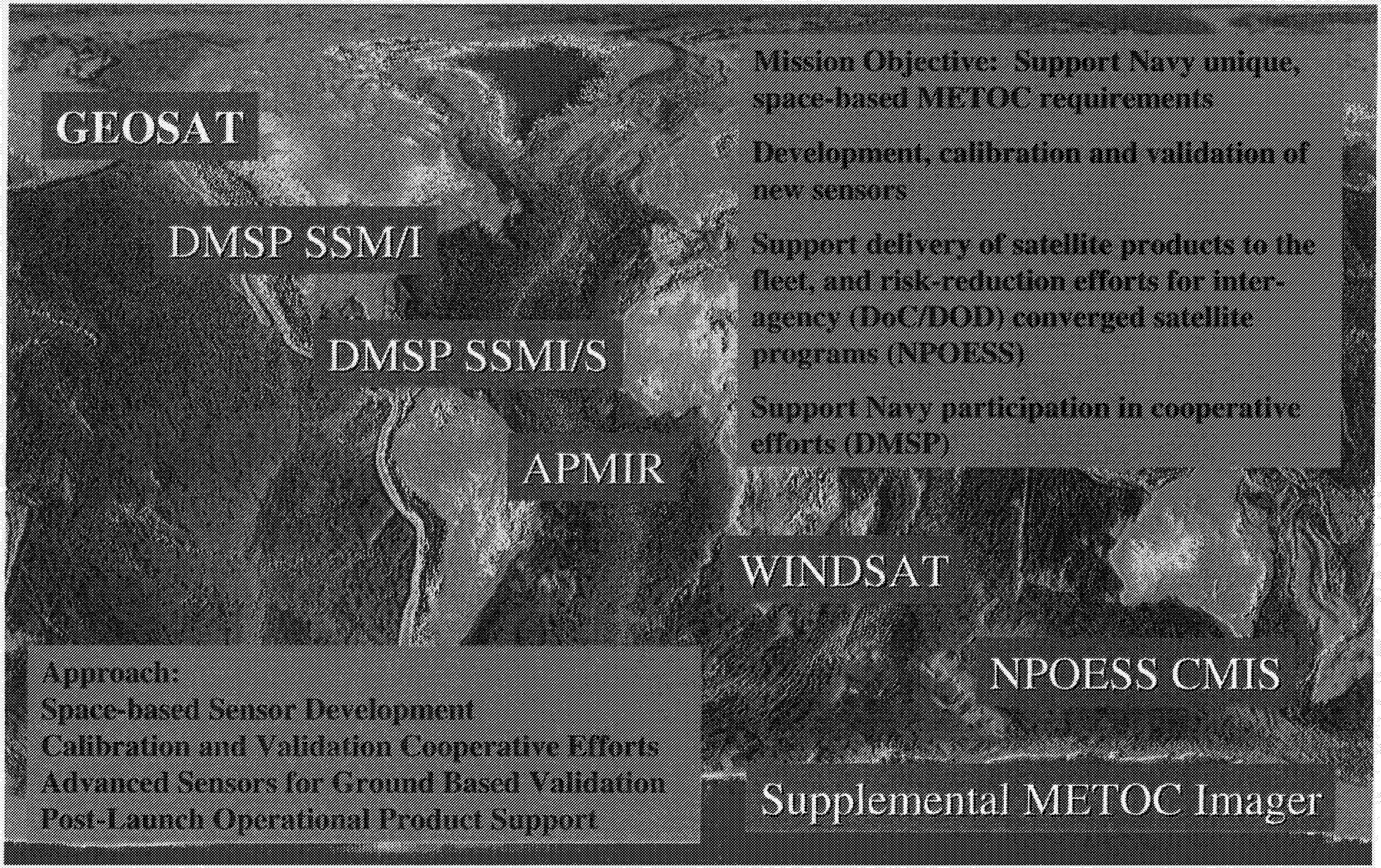
- High Time & Space Resolution Ionospheric Imaging
  - Precision Geolocation of Emitters
  - Improved GPS Accuracy
  - Satellite Altimetry (GFO)
  - Theater Ballistic Missile Defense
- Real-Time Tracking of Ionospheric Irregularities & Scintillation Regions
  - Reduced Communication & Navigation Outages (UHF, HF, GPS)
- Possible Piggyback for Indian Ocean Geostationary Satellite
  - Space Flight Support from Space Test Program
  - Synergistic with USAF C/NOFS ACTD





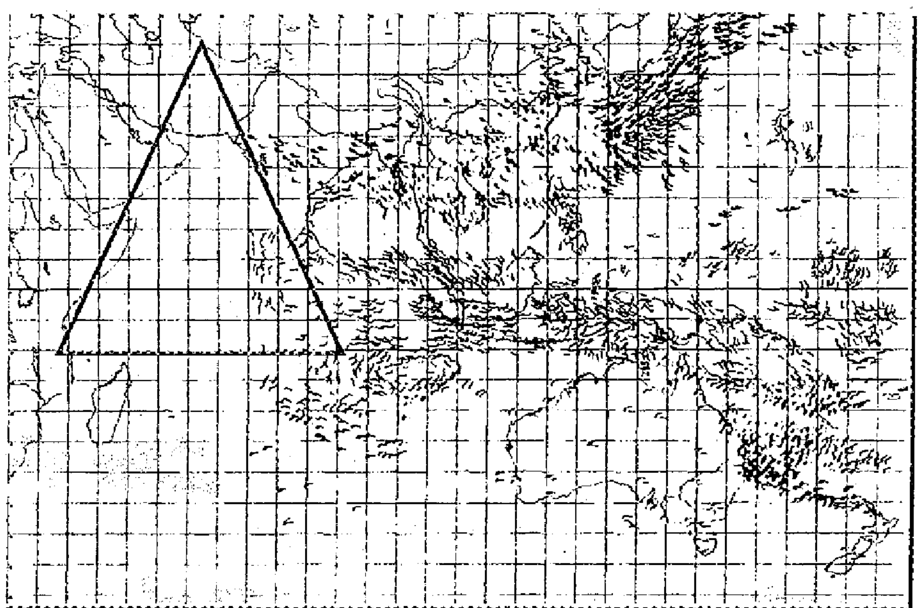
Apollo 17 Ultraviolet Image of the Earth

NAVY METOC SENSORS - SPACE



METOC Imager: Indian Ocean

High Priority CINC Requirement: *High Resolution Visual & IR Imagery of the Indian Ocean*



Sponsors: CNO(N6) and CNO(N096)

Program Management: ONR 32SO (Space Office)

Conceptual Approach:

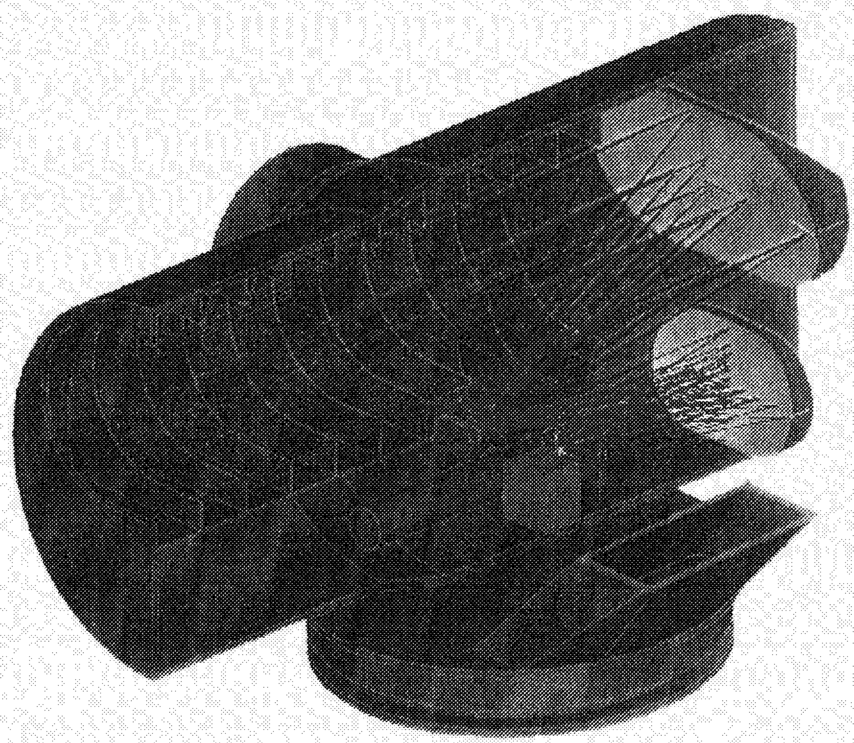
National/DoD/Industry Partner for Satellite and Launch
Industry Partner for Sensor

- **METOC Imagery Requirements**
  - Clouds and fog
  - Cloud drift winds
  - Cloud Top Height
  - Secondary Requirements
    - Cloud heights
    - Water Vapor Winds
- **Sensor Requirements for Primary Parameters**
  - Vis 0.55 - 0.75 μ
  - IR 7.1 - 13.6 μ
  - 10 or 12 bit precision
  - 100 kg, 0.75 m^3, 100W
- **Space/Time Requirements**
  - Hi-resolution (1 km day/4 km night)
  - 2 hour refresh, full disk
  - ≤30 minute refresh, sector
  - 3 km geolocation
- **Current Activities:**
  - Raytheon Study Completed
  - Lincoln Lab System Study In Process
  - Non-Acquisition Program Definition Document (NAPDD) being Developed for Summer FY99 Submission
  - Satellite/Launch Vehicle Options Being Explored

Raytheon

Santa Barbara Remote Sensing

SMI Sensor Concept

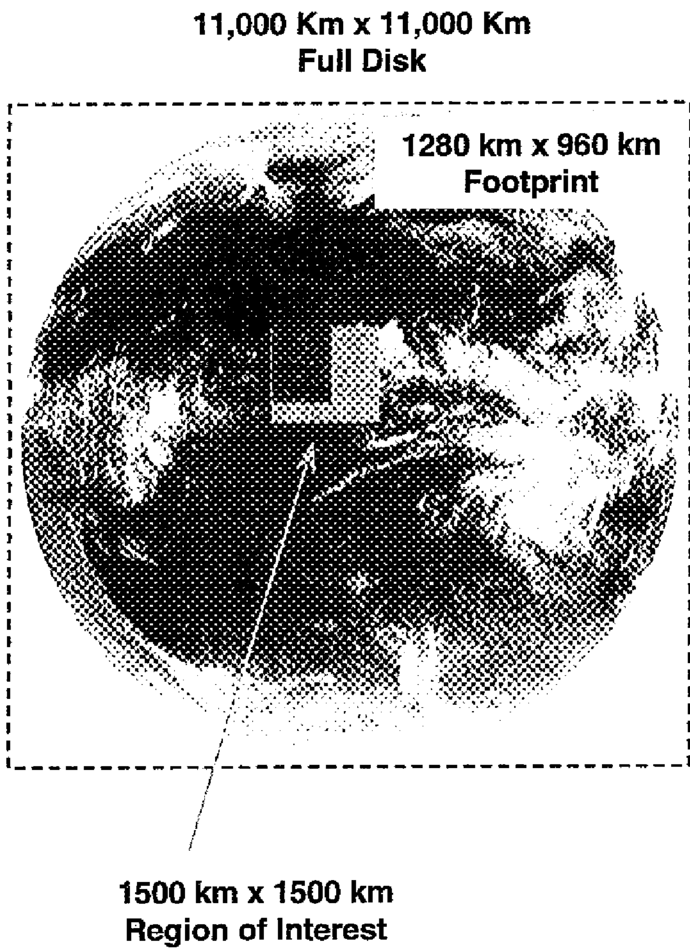


- 30 cm aperture off axis telescope or 2-axis gimbal
  - Compact package minimizes impact on spacecraft
  - Off axis three mirror design provides superior imaging and minimizes solar intrusion effects
- Two area arrays, one each for the visible and IR
  - 1280 x 1280 CCD array
  - 320 x 240 uncooled IR array
  - Filter wheel enables IR band selection
- Projected mass: 82 kg
- Projected volume: 0.5 m^3
- Projected power: 80 W (avg), 120 W (peak)

Raytheon

Santa Barbara Remote Sensing

Projected SMI Capabilities



- Provide visible and infrared images showing clouds, storms, water vapor, winds and surface temperature
- 1 km resolution in one visible band
  - 0.55 to 0.75 µm
- 4 km resolution in three infrared bands
  - 7.1 to 7.5 µm
  - 10.2 to 11.2 µm
  - 13.1 to 13.6 µm
- 42 min full disk revisit
- 1.3 min revisit for 1500 km x 1500 km region
- Data rate ~450 kbps to meet Navy's reporting requirements and is compatible with AN/SMQ-11 system
- Environmental data performance similar to GOES for mission parameters

- Naval Space S&T Program Office Overview
- Navy Payloads
- GEO Mission
- Enabling Technologies
- Summary

Supplemental Metoc Imager (SMI)
Proposed Partnership

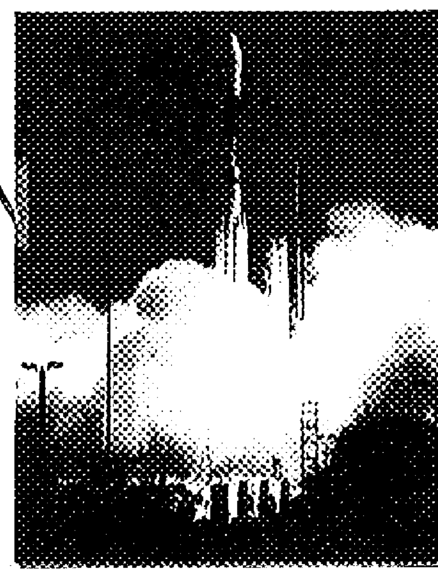
NAVY:

Maximize Leverage of Dollars
Acquire Partners
Technology Transition

Total S/C & Launch: $90M

1/3 Cost

SMI
Enabling Technologies



NASA

Experiments
Sensor(s)
Technologies

1/3 Cost

INDUSTRY Partner or Other GOV'T

Experiments
Sensor(s)
Technologies

1/3 Cost

- Naval Space S&T Program Office Overview
- Navy Payloads
- GEO Mission
- Enabling Technologies
- Summary

Summary

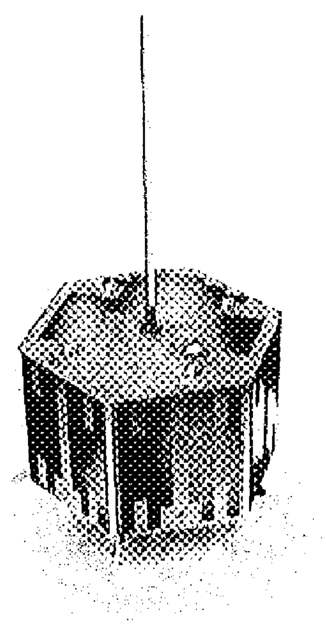
- **Navy Has Defined GEO Requirements**
  - Looking for Partner(s)
    - Government and/or Industry

- **Emerging Technologies Can Enable More Capable GEO Bus**
  - Cost Effective Frequent GEO Missions

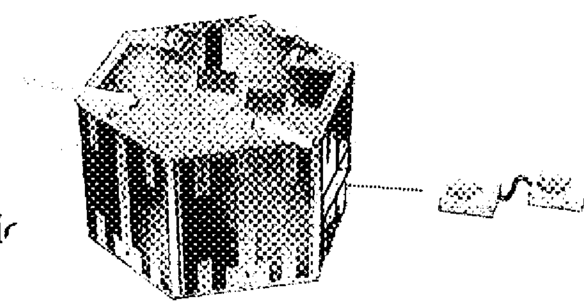
- Call me... 703-588-0702

Student Micro/Nano Space Applications

RideShare Conference
Litton/TASC
Chantilly, VA
April 15-16, 1999



Prof. Robert J. Twiggs
Department of Aeronautics & Astronautic
Stanford University
Stanford, CA

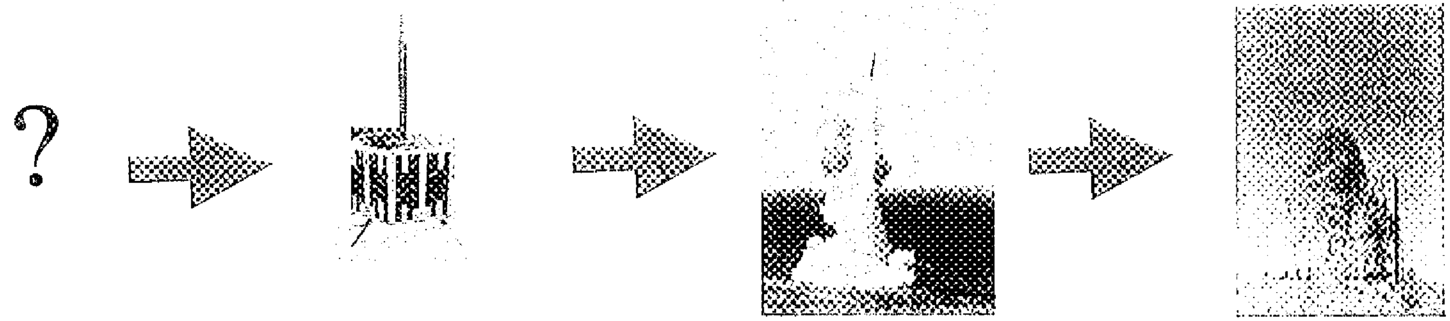


University Space Projects

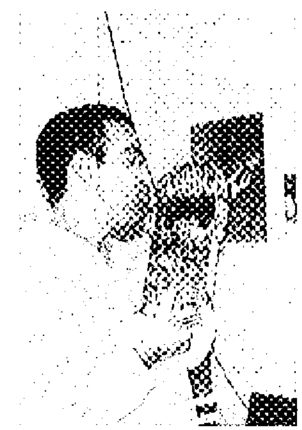
- **Weber State University**
  - Started 1982 — NUSAT - 1985 AMSAT/Microsats - 1990
- **University of Alabama- Huntsville**
  - Started ~ 1988 — Sedsat - 1999
- **Arizona State University**
  - Started ~ 1993 — ASUSat1 - OSP Launch 1999
- **Naval Postgraduate School**
  - Started ~ 1986 — Shuttle Launched 1999
- **Stanford University**
  - Started 1994 — Sapphire - Ready to launch (no Launch)
    OPAL - OSP Launch 1999
- **Nanosat Program**
  - Started 1999 — Ten Nanosats Launch 2001
- ....

Space Programs for Education

- **Educational Goals & Challenges**
  - ➢ Provides Project Life-Cycle Experience



  - ➢ Student Managed
  - ➢ Student Run



VERY UNSTRUCTURED

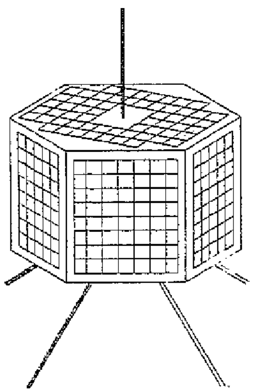
Projects

- **Microsatellite Design Program - MS Level**
  - SQUIRT Class - 20 kg
- **Advanced Spacecraft Development - Ph.D.**
  - 40 - 100 Kg
  - SHARP - Atmospheric Reentry Vehicle for Thermal Systems Protection Tests
- **Spacecraft Operations Research - Ph.D.**
  - ASSET - Autonomous Space Systems Experimental Testbed
- **Other - Undergraduate**
  - Ares
  - CanSat
  - Barnacle

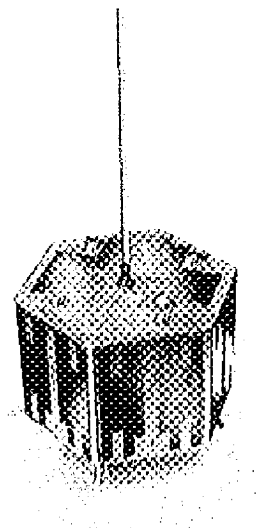
Project Cost Range

	Material Cost
Graduate	
SQUIRT - <20 kg nano/micro satellite ------ MS Degree Project	<$50,000
Advanced Programs - < 50 kg	
Orion - formation flying - Engr/Ph.D. Project	~$150,000 - $250,000
SHARP - hypersonic reentry vehicle test bed - Engr/Ph.D. Project	~$250,000
Undergraduate/Pre College	
Picosats - payloads for microsatellites - Santa Clara University	~$1,000
Ares - remote data collection - Antarctic -> Mars	~$5,000
CanSat - new challenge - University of Tokyo, Tokyo Institute of Technology, Stanford University, University of Texas - Austin	~$1,000

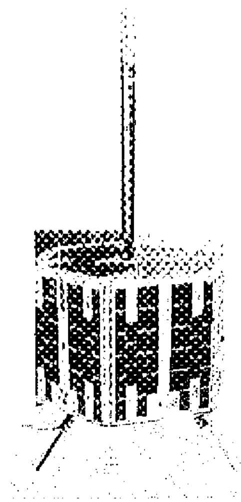
SAPPHIRE - Microsatellite



Visio
n



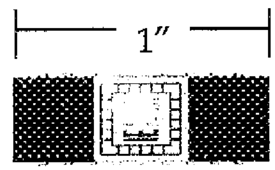
Concept



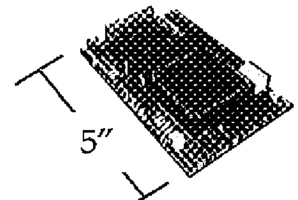
Reality

18 " Diameter
12 " Height
22 kg Weight

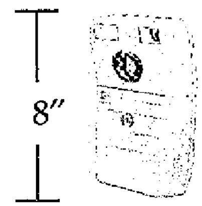
Payloads



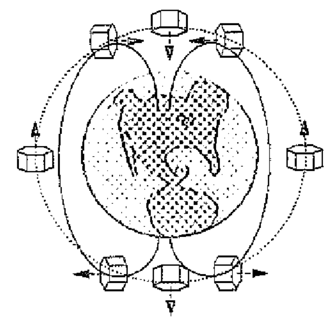
MEMS Infrared Sensor



Voice Synthesizer



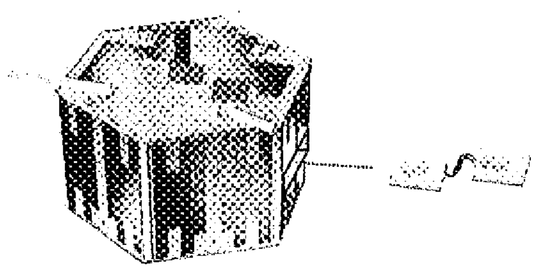
B/W Digital Camera

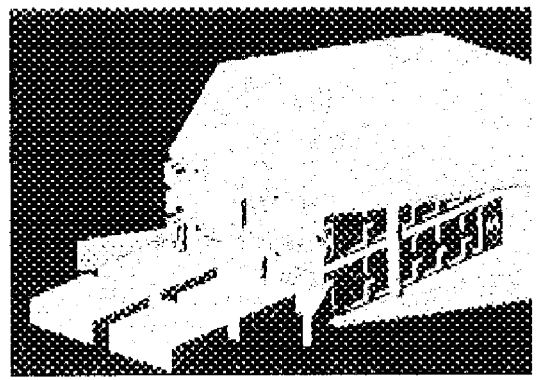


Passive Magnet Stabilized

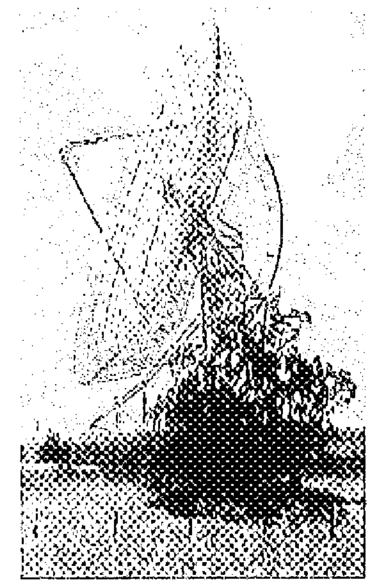
Stanford's First Student Built Microsatellite
Ready to Launch July 1998

OPAL - Microsatellite





Picosat Launcher



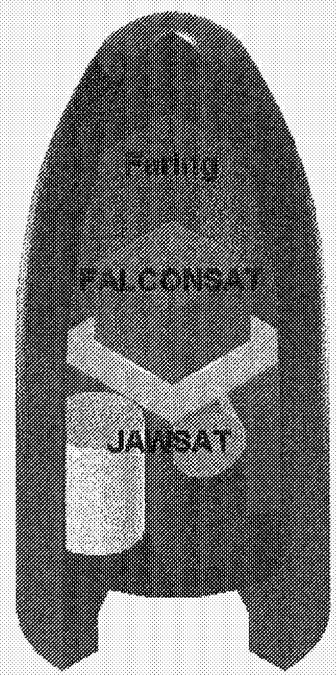
Mother - Daughter Spacecraft

50 m Diameter Astronomy Antenna
For Picosat Communications

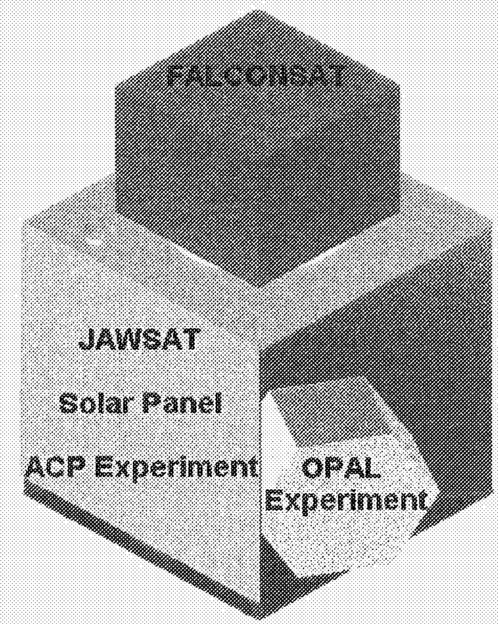
Stanford's Second Student Built Microsatellite Scheduled Launch September 15, 1999

Low-cost Testing of New Technologies

JAWSAT/OSP Launch

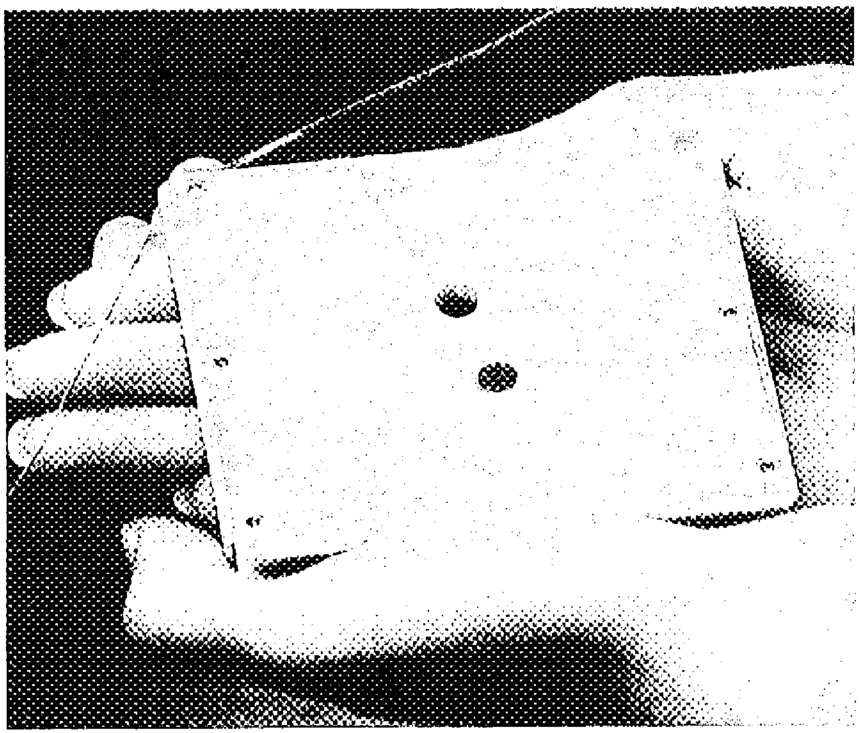


OSP Vehicle With JAWSAT



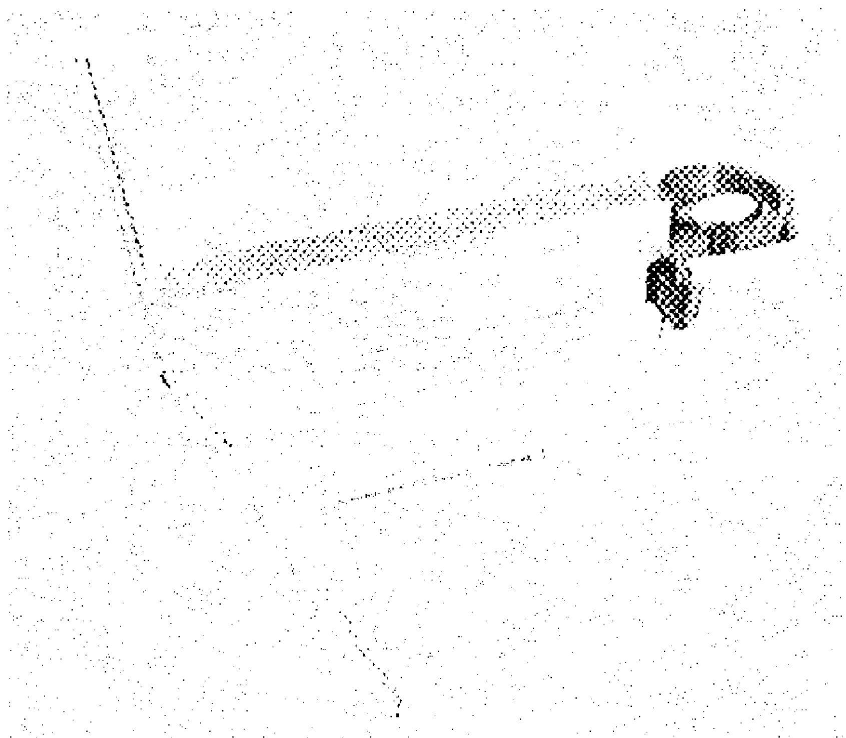
JAWSAT with OPAL

Artemis 4-inch Picosatellite



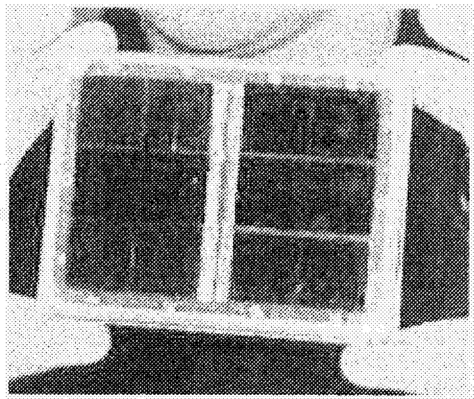
- Transmitter beacon
- Transmits Artemis web site address

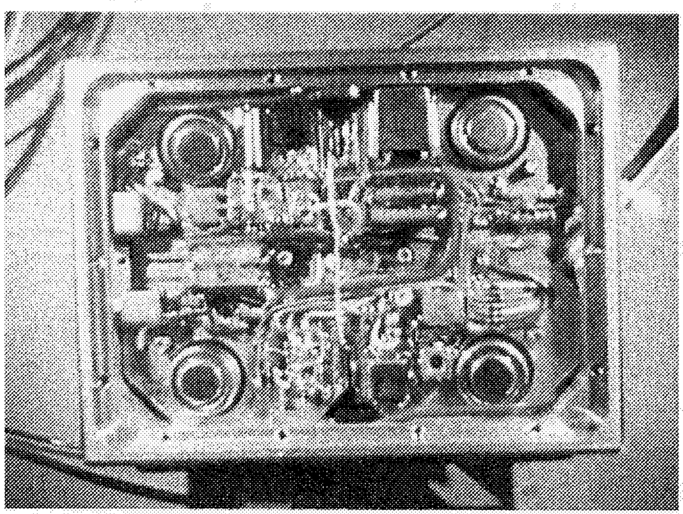
Artemis 8-inch Picosatellites



- Study VLF emissions from thunder clouds
- Record 15 seconds of simultaneous data at 11 kHz
- Compare two data sets to approximate ionospheric aberrations

Stensat Picosatellite

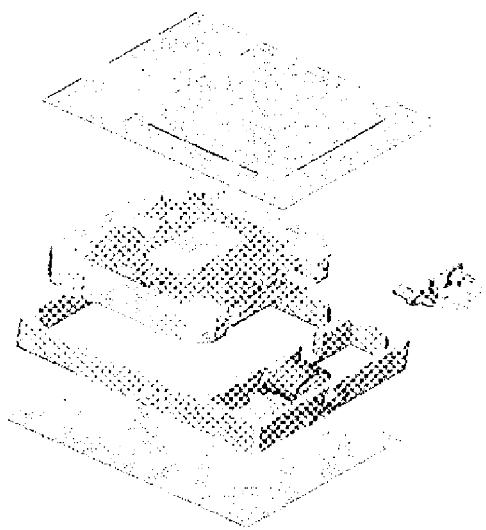




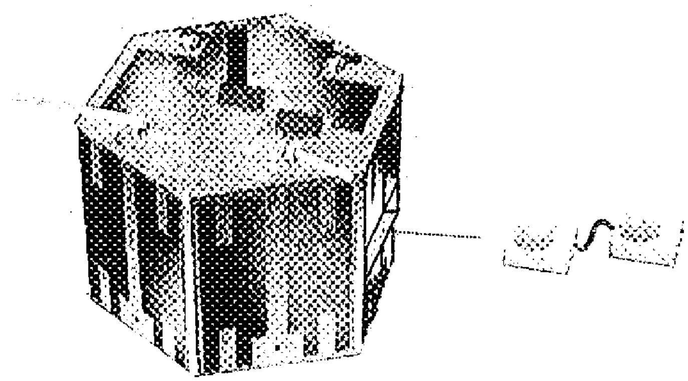
- single channel mode "J" FM voice repeater
- uplink at 145.84 MHz downlink at 436.625 MHz
- periodically transmits telemetry
- amateur radio operators able to "PING" the satellite causing it to broadcast a telemetry packet

Aerospace Corp. Picosatellites

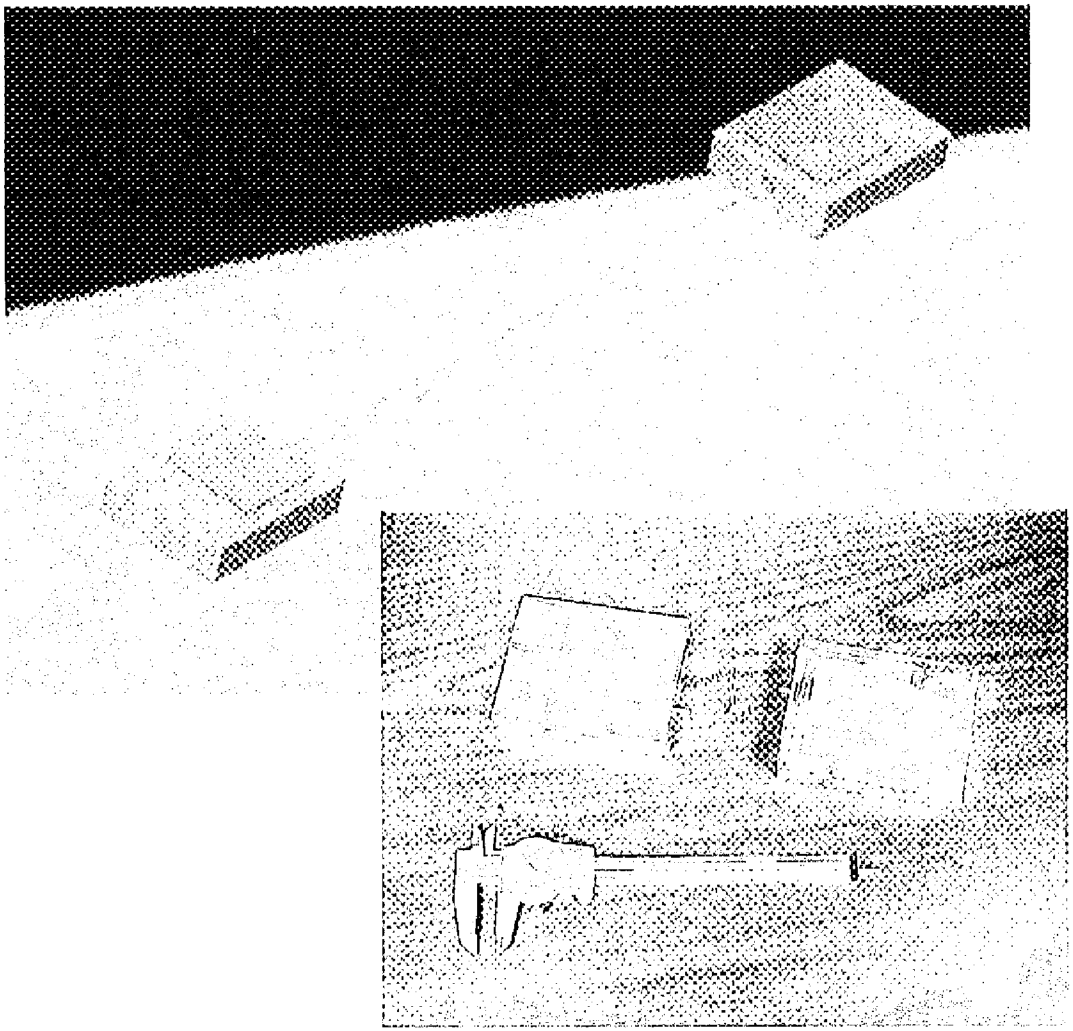
Picosatellite Stack



Ejection from OPAL

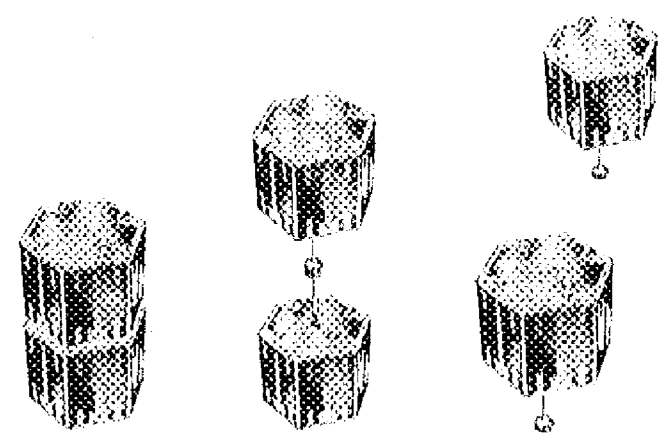


Aerospace Corp. Picosatellites



- Two tethered picosatellites
- Testing DARPA MEMS RF switches
- Testing of inter-satellite communications link and protocol

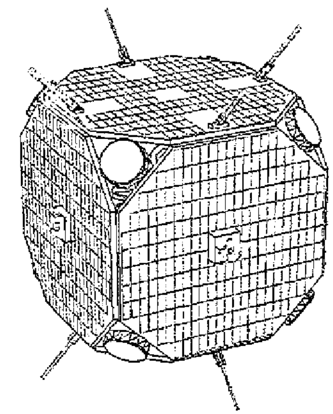
Emerald - Nanosatellite



Advancing Formation Flying with Student Built Nanosatellites

Stanford's Third Student Built Microsatellites Scheduled Launch Early 2002

Orion - Formation Flying

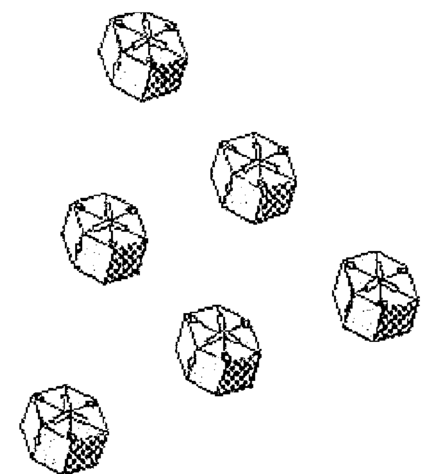


Vision - Distributed, highly coordinated satellites perform a unified mission

Advantages - Large baselines, graceful degradation, flexible deployment

The Stanford Orion Project

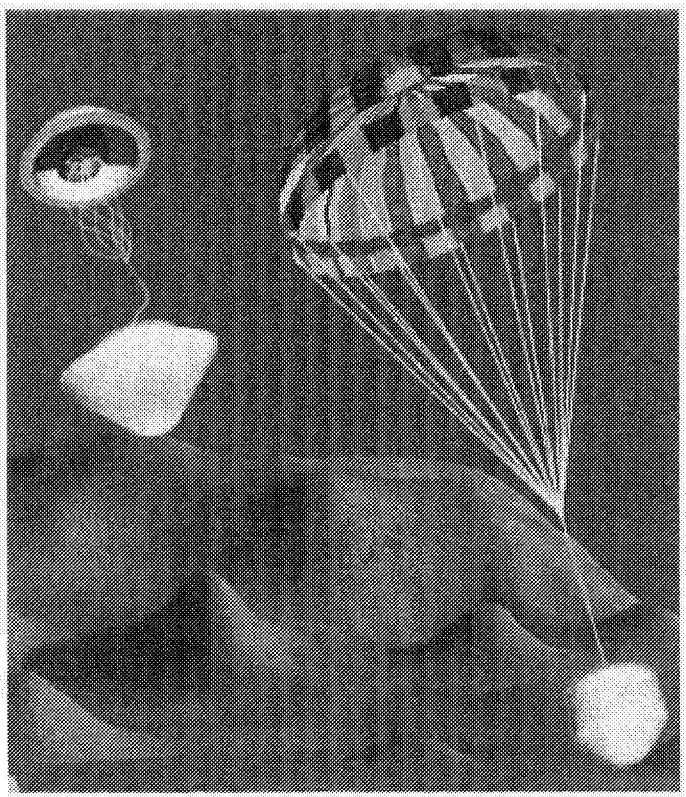
- Sub-meter relative position control
- 3-6 spacecraft formation
- 40 kg, 3-axis control, cold gas thrusters



Stanford's First Advanced Microsatellites Scheduled Launch Early 2002

Ares Mars Project

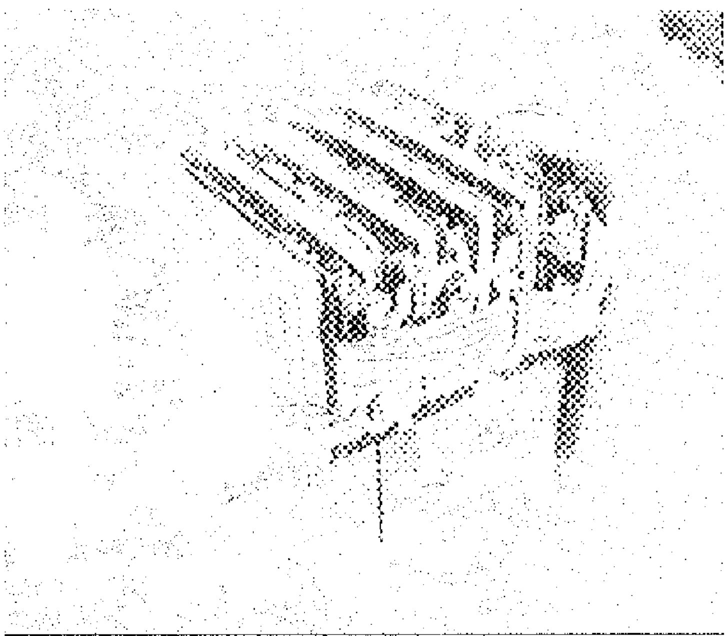
Mars Imaging with Weather Probe



- Undergraduate project
- Camera in nose of probe
- Collect imaging data on descent
- Store images
- Transmit through Mars orbiter to earth
- Need space test before Mars

Barnacle Project

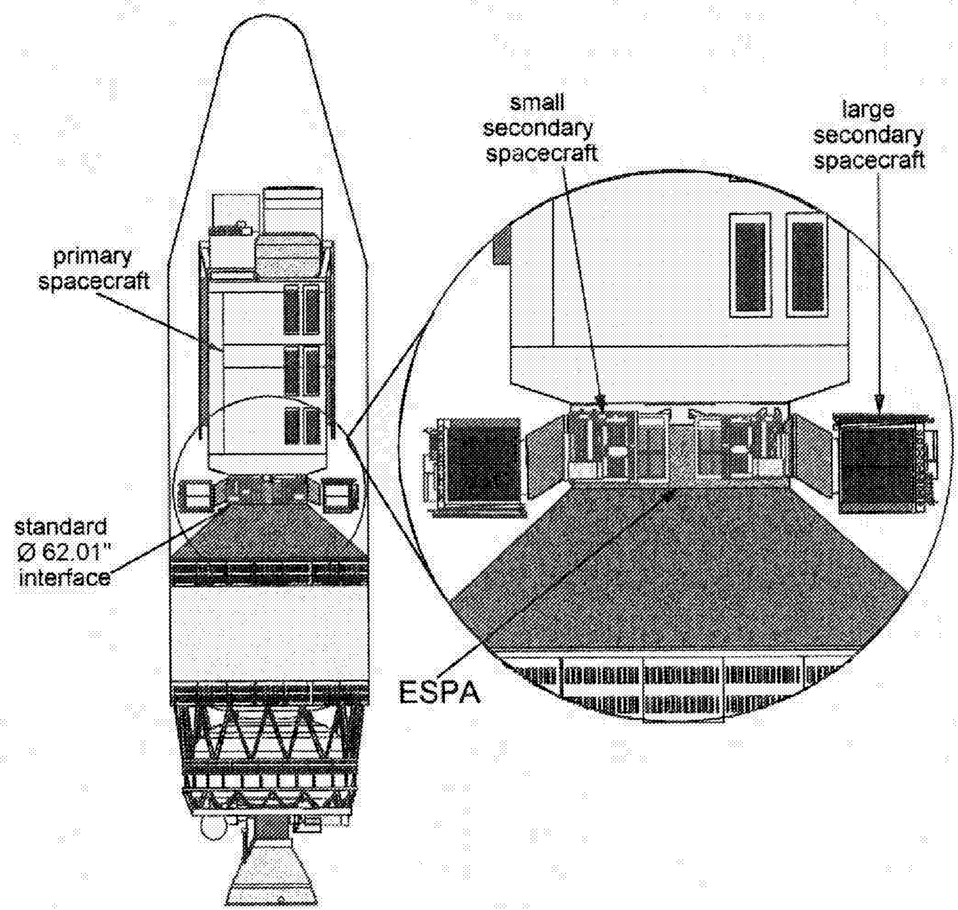
Parasat class



- Undergraduate project
- Permanently attached to last stage of ELV
- Battery operated
- Comm system with uplink and downlink
- Short life testing
- Any orbit

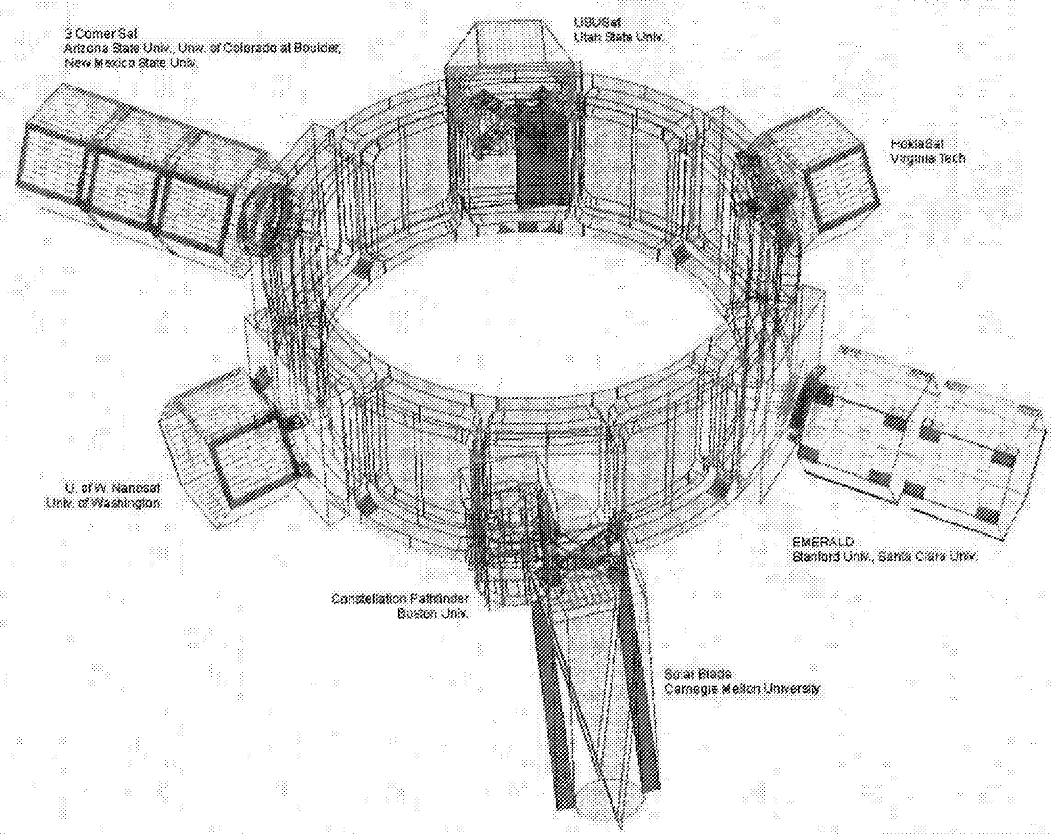
ESPA

Secondary Launches



ESPA

Nanosat Program Secondary Launches

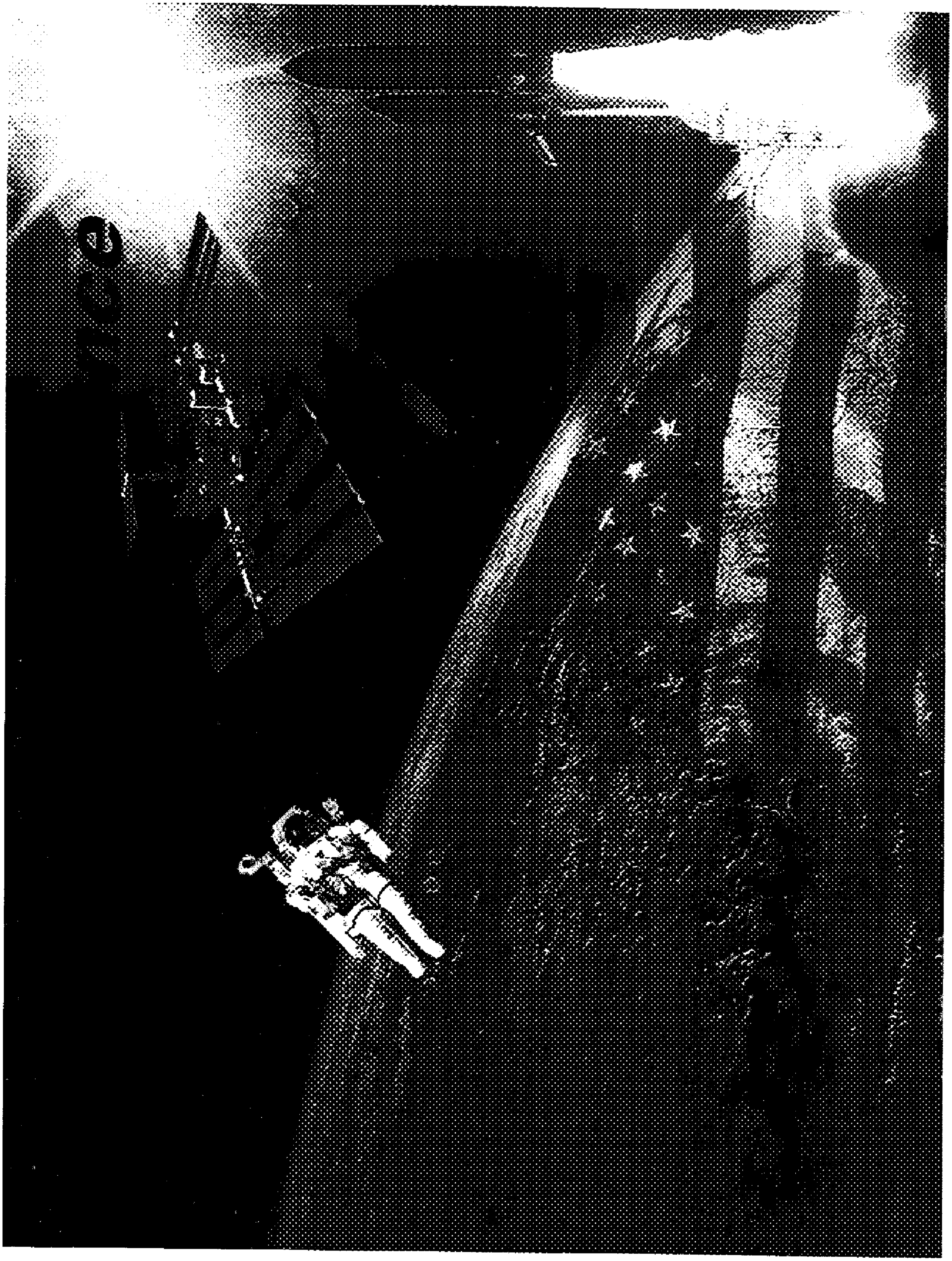


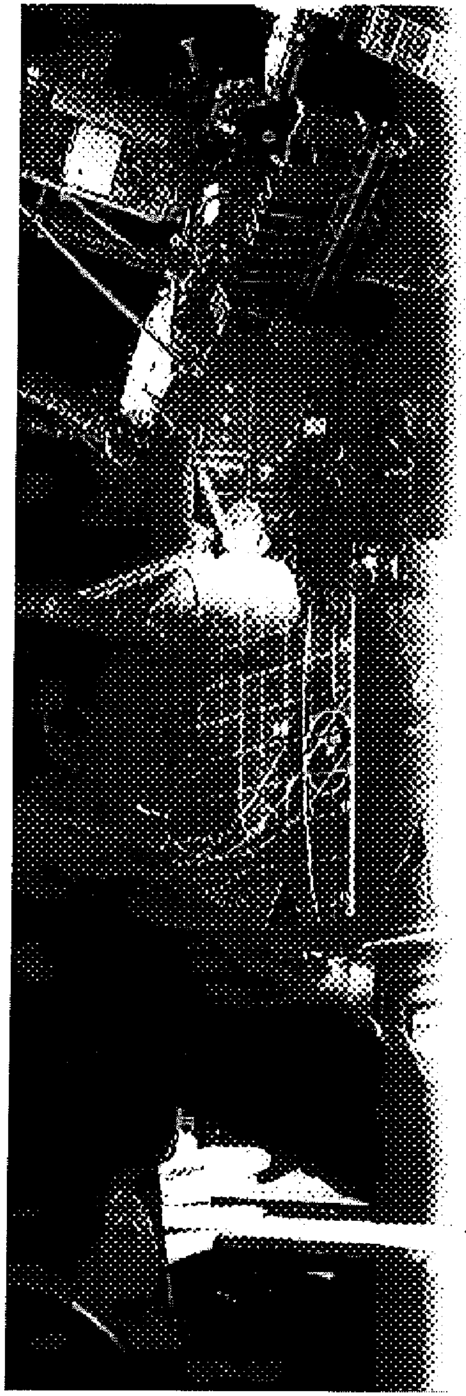
Conclusions

Need for Secondary Launches

- Many university programs
- Many projects
- Excellent drivers for student education
- Trained engineers for industry and government labs

Projects for Really GOOD GOOD Education





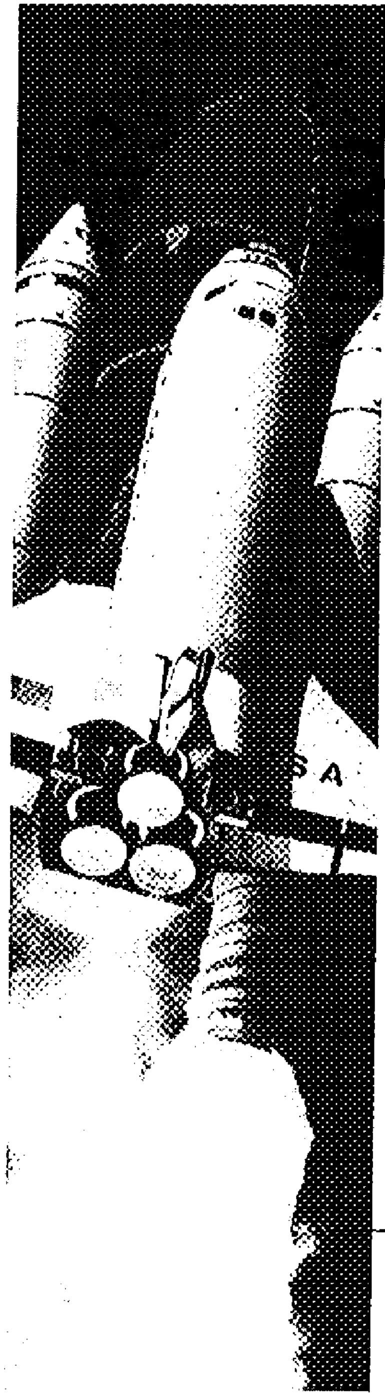
United Space Alliance

Products and Services for Space Operations

- Space Hardware Processing
- On-Orbit Operations
- Launch & Return Operations
- Space Systems Training

NASA's single prime contractor for Shuttle operations

USA
United Space Alliance



"Reimbursable Missions"

- Two Flight opportunities on OV-102, Columbia
  - "marketing of payloads … positive step toward our goal of privatizing /commercializing"
  - flight opportunities shown on manifest are 6/02 and 7/03
    - these are place-holder dates; actual dates will be defined by primary payload launch requirements
- USA to lease Shuttle payload bay
  - payload customers charged pro-rated amount based on use of Shuttle resources

United Space Alliance

"Reimbursable Missions"

- Services provided by USA
  - manifest payload
  - single point of contact for payload
  - interface with NASA on behalf of payload
  - arrange/provide upper stage and/or carriers/cradles, if necessary
  - payload integration
  - on-orbit support

USA
United Space Alliance

"Reimbursable Missions"

- United Space Alliance offers turnkey solutions to getting your payload into space

To learn more about flight opportunities:

Therese Thrift

Director, Strategic Business Planning

281.280.6958

SPACEHAB®

WE MEAN BUSINESS IN SPACE™

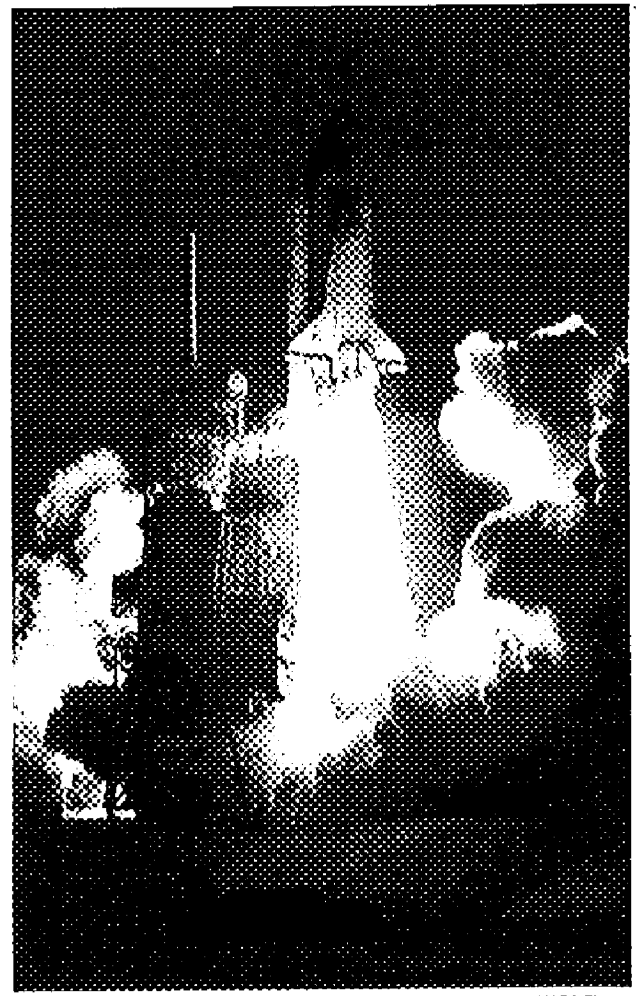
Commercial Space Hardware Capabilities

Chris Martin

April 1999

Provide an overview of SPACEHAB and its ability to "fly" payloads for the NRO.

- Company Overview
- Overall Capabilities
- Integration Process
- Contractual Arrangements
- Summary



NASA Photo

➢ SPACEHAB, Inc.

- The leading commercial space services company supporting both manned and unmanned missions to space
- First company to develop, own and operate habitable modules that provide space-based laboratory research facilities and cargo re-supply services aboard the U.S. Space Shuttle fleet

➢ ASTROTECH

- Offers customers a commercial alternative to the Government payload processing facilities at the Kennedy Space Center, with the full cooperation of NASA
- Provides Payload Processing for Civil and Commercial Satellites
- Leading commercial provider of launch processing services in the United States

➢ Johnson Engineering

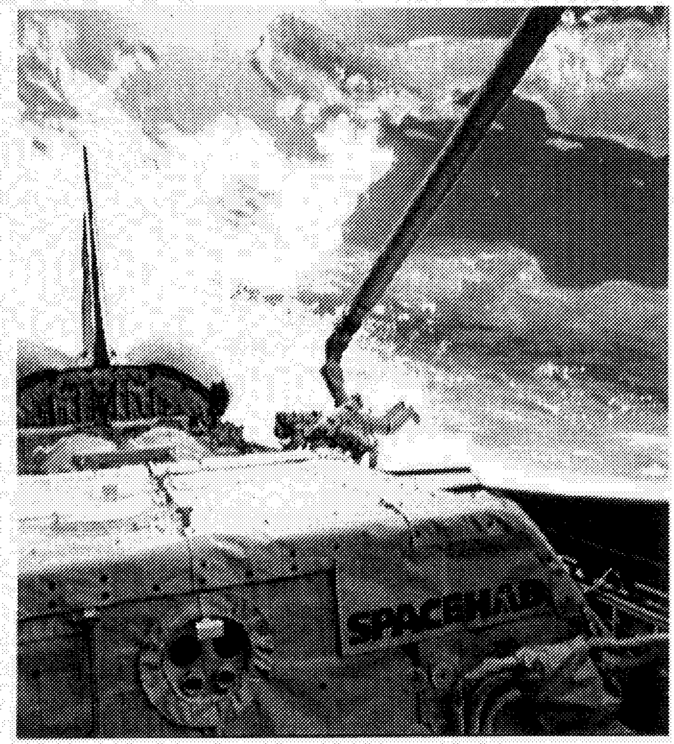
- A highly diversified enterprise primarily engaged in design, development, fabrication and integration of technology products and services
- The company's core businesses include design engineering for electrical, mechanical, and software systems, aquatic/ocean engineering, fabrication, space systems, and systems integration

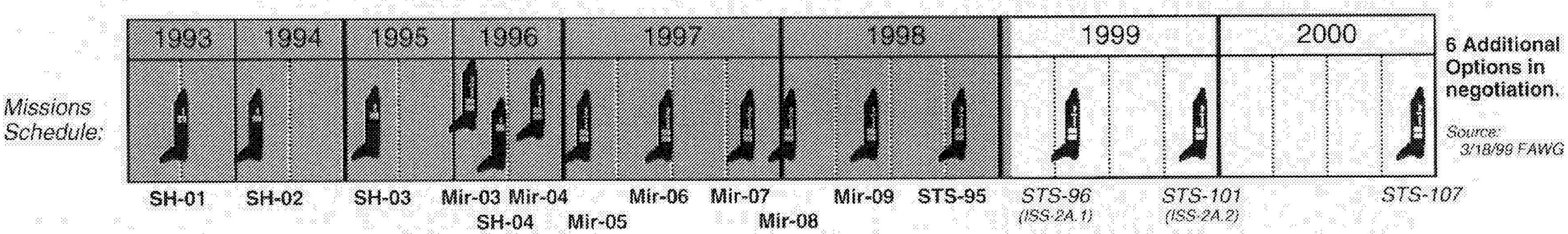
Business Model

- Identify undefined requirements
- Create products & services to satisfy requirements
- Invest private capital to build assets
- Price according to value assessment
- Determine project viability at this price

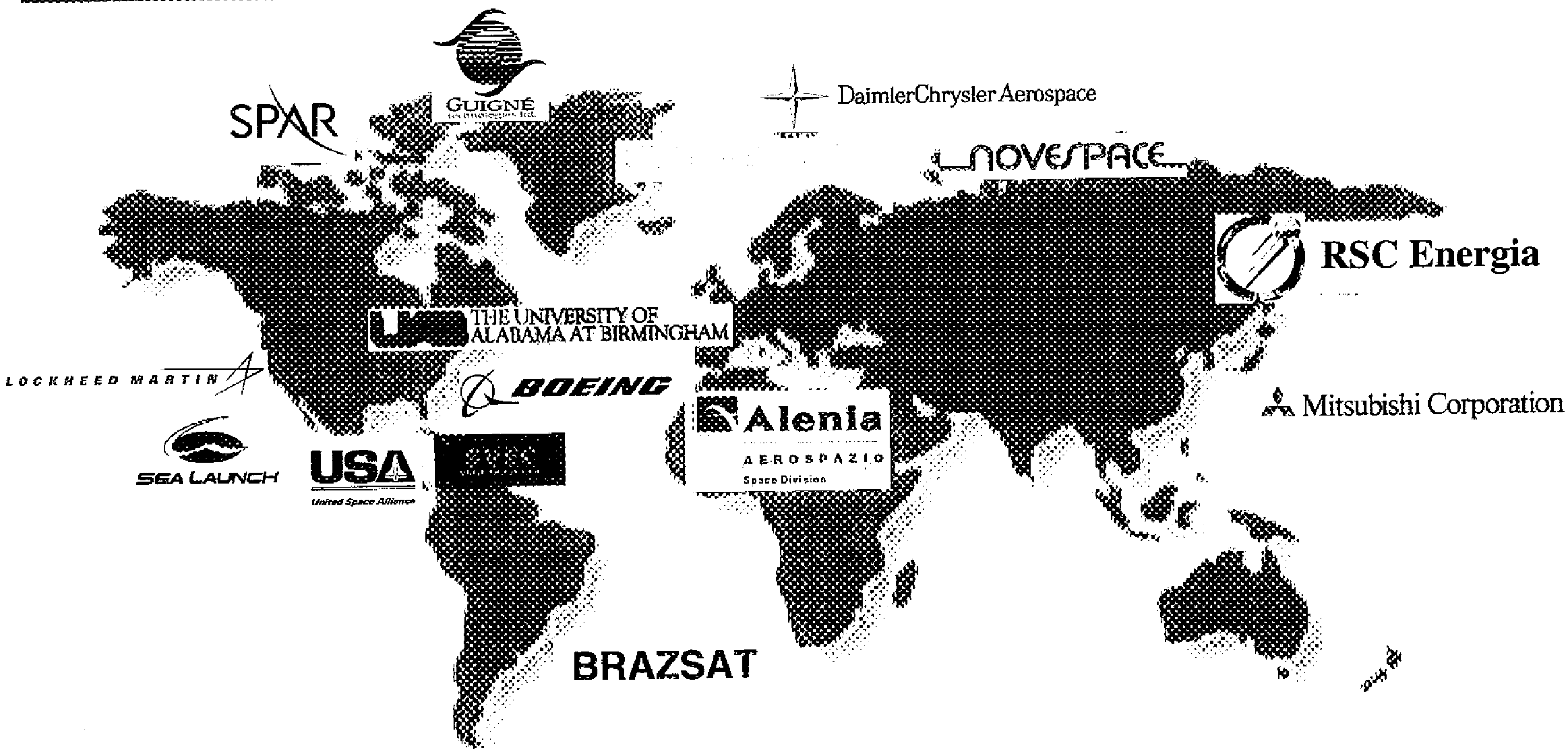
Missions

- Twelve successful missions on two NASA contracts - Space Shuttle research and cargo resupply to *Mir* space station
- Over 100 experiments flown in Module, Middeck, and on roof top
- Additional Shuttle research and ISS cargo resupply missions under REALMS contract

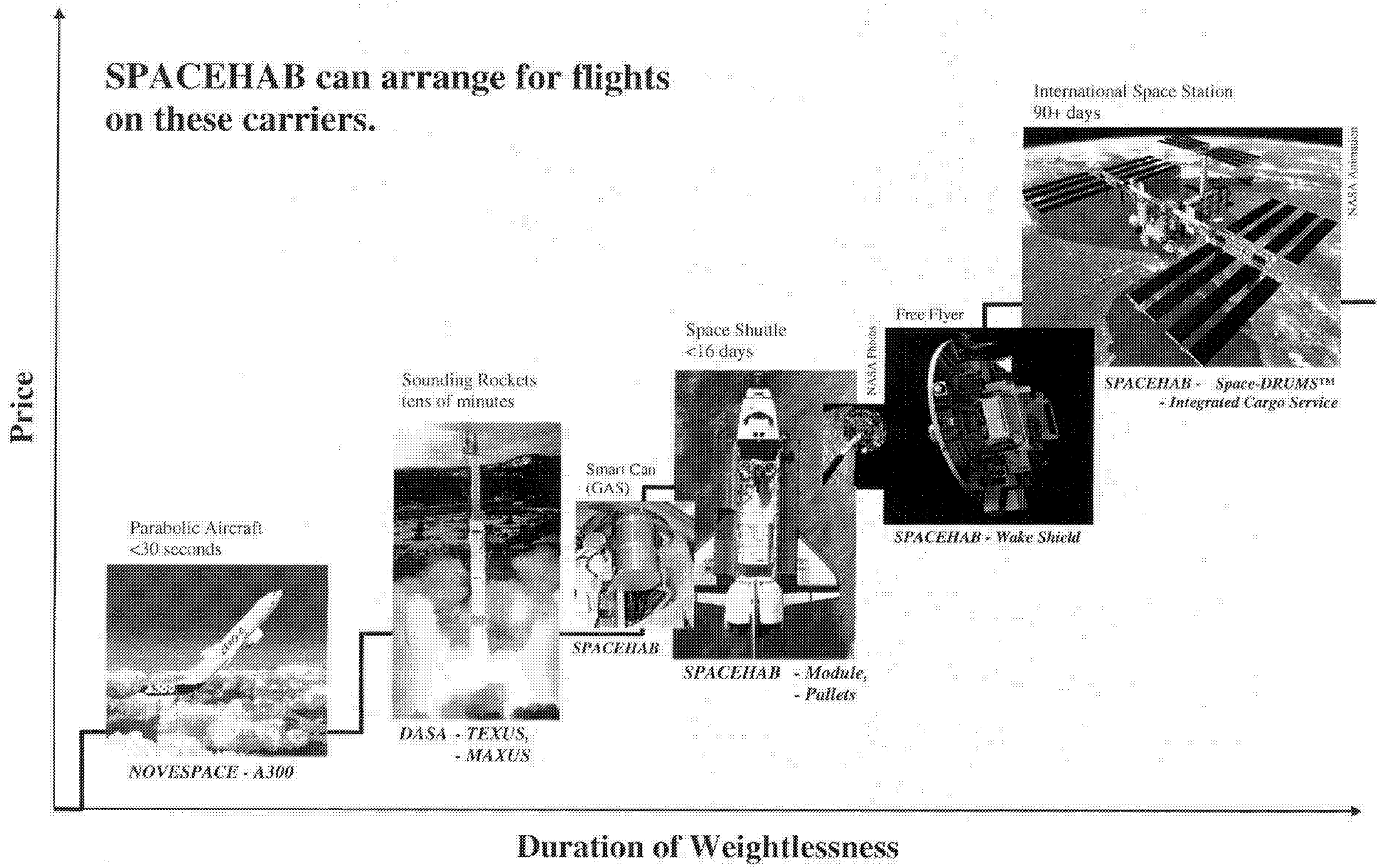




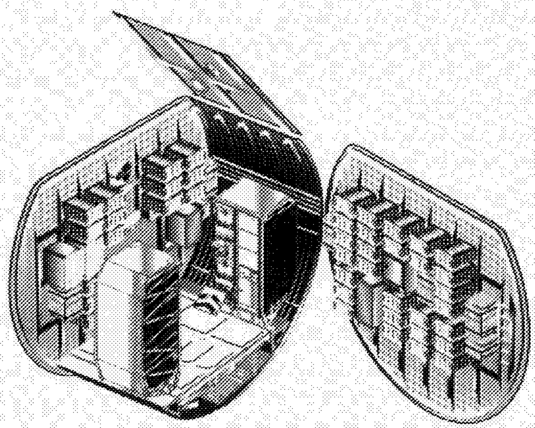
International Alliances



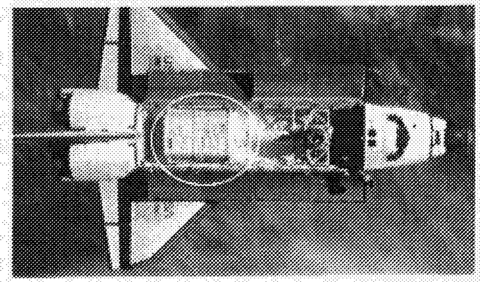
- SPACEHAB has relationships with an international alliance of space-related organizations.


SPACEHAB can arrange for flights on these carriers.
Price
Parabolic Aircraft
<30 seconds
NOVESPACE - A300
Sounding Rockets
tens of minutes
DASA - TEXUS,
- MAXUS
Smart Can
(GAS)
SPACEHAB
Space Shuttle
<16 days
SPACEHAB - Module,
- Pallets
NASA Photos
Free Flyer
SPACEHAB - Wake Shield
International Space Station
90+ days
NASA Animation
SPACEHAB - Space-DRUMS™
- Integrated Cargo Service
Duration of Weightlessness

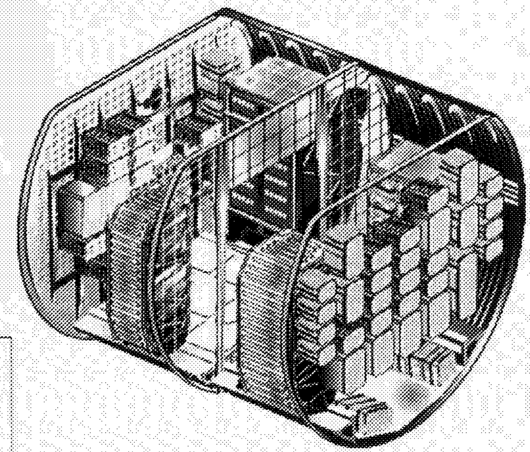
Modules for Various Missions



Single Module



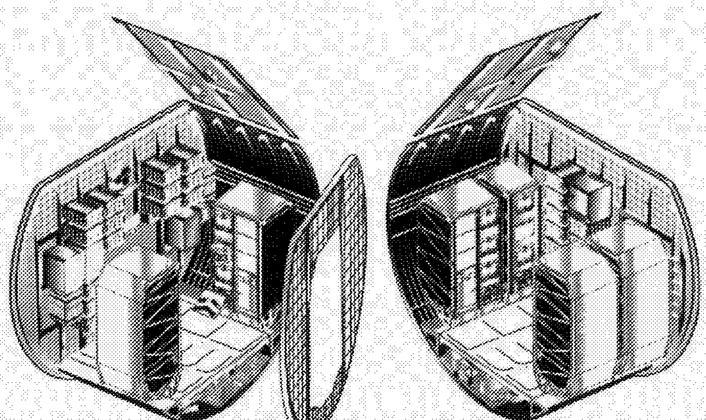
NASA Photo
Double Module Exterior



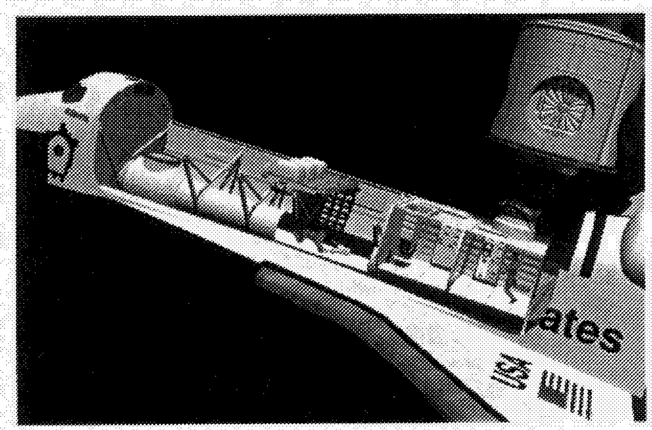
Logistics Double Module

- Modules for Shuttle research, Station resupply and reboost
- Module used varies by need
- All can carry active research

Research | *Station Cargo*

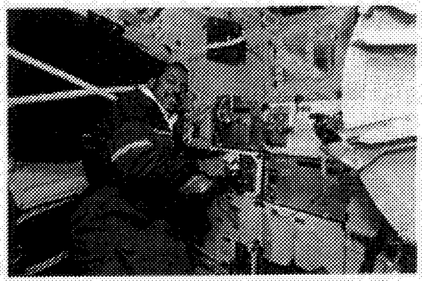


Research Double Module



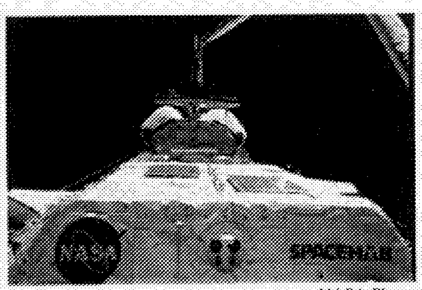
Docking Double Module

Current Capabilities

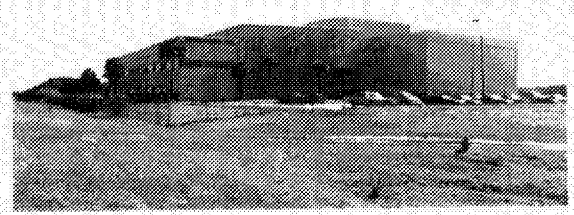

NASA Photo
Middeck, SPACEHAB Lockers


NASA Photo
SPACEHAB, ISS Racks


NASA Photo
Oversized Cargo to Mir,
Fabric Cargo Transfer Bags



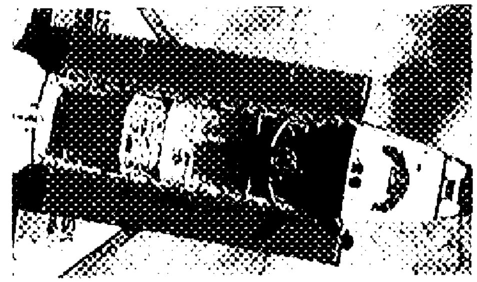
NASA Photo
External Payloads


Integration Facility

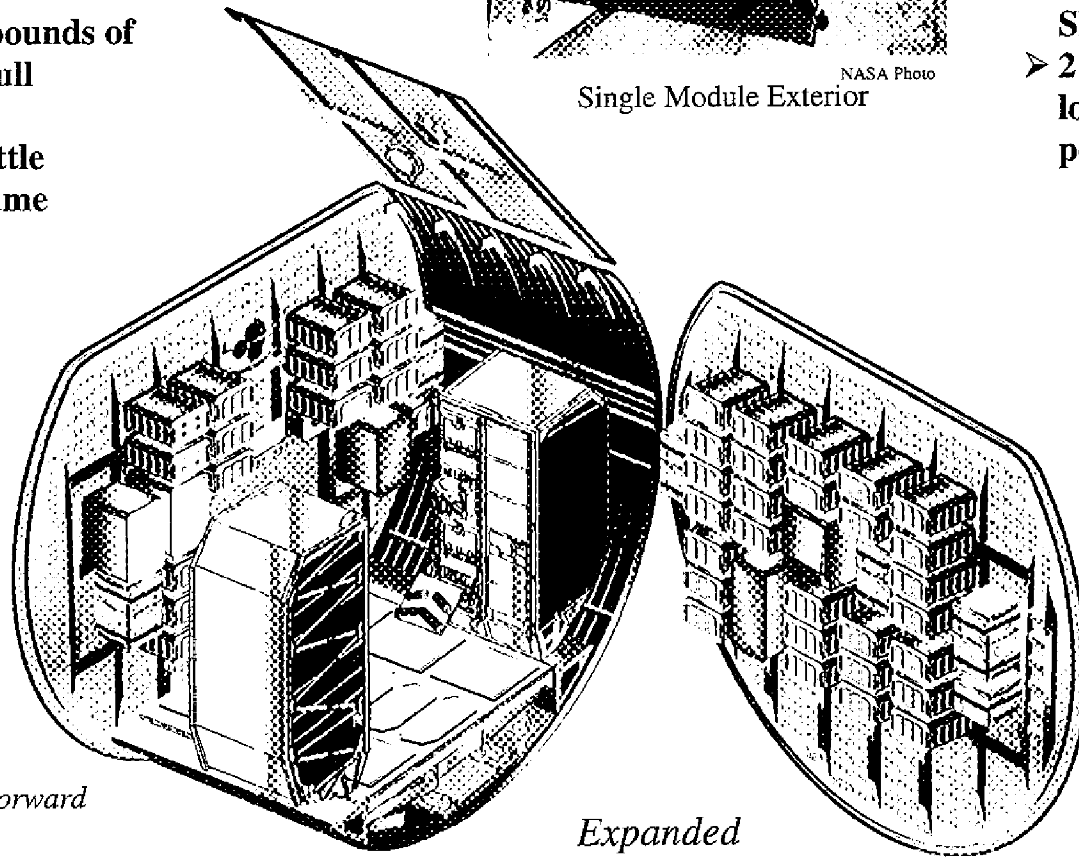
- **Module missions include :**
  - Middeck lockers
  - SPACEHAB lockers & racks
  - Station ISPRs
  - Exposed rooftop payloads
  - Fabric transfer cargo bags
  - Oversized cargo items
- **Payload resources include:**
  - AC and DC power
  - Air and water cooling
  - Crew time support
  - Downlink data and video
  - Uplink commanding
  - Vacuum venting
- **9-15 month integration**
- **Off-site integration facility**
- **Many payloads reflown from Middeck, Spacelab**

Single Module

- Flown several times in logistics and science support roles
- Provides 4800 pounds of payloads with full resources
- Maximizes Shuttle co-payload volume

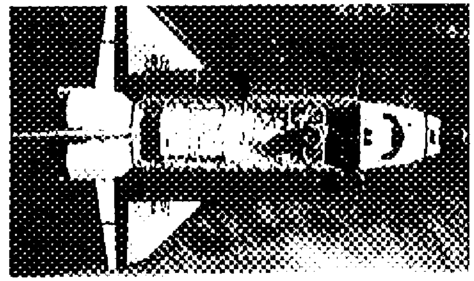

NASA Photo
Single Module Exterior

- Lockers flown on both bulkheads
- Can house 2 ISPR or SPACEHAB racks
- 2 external rooftop locations at 500 pounds



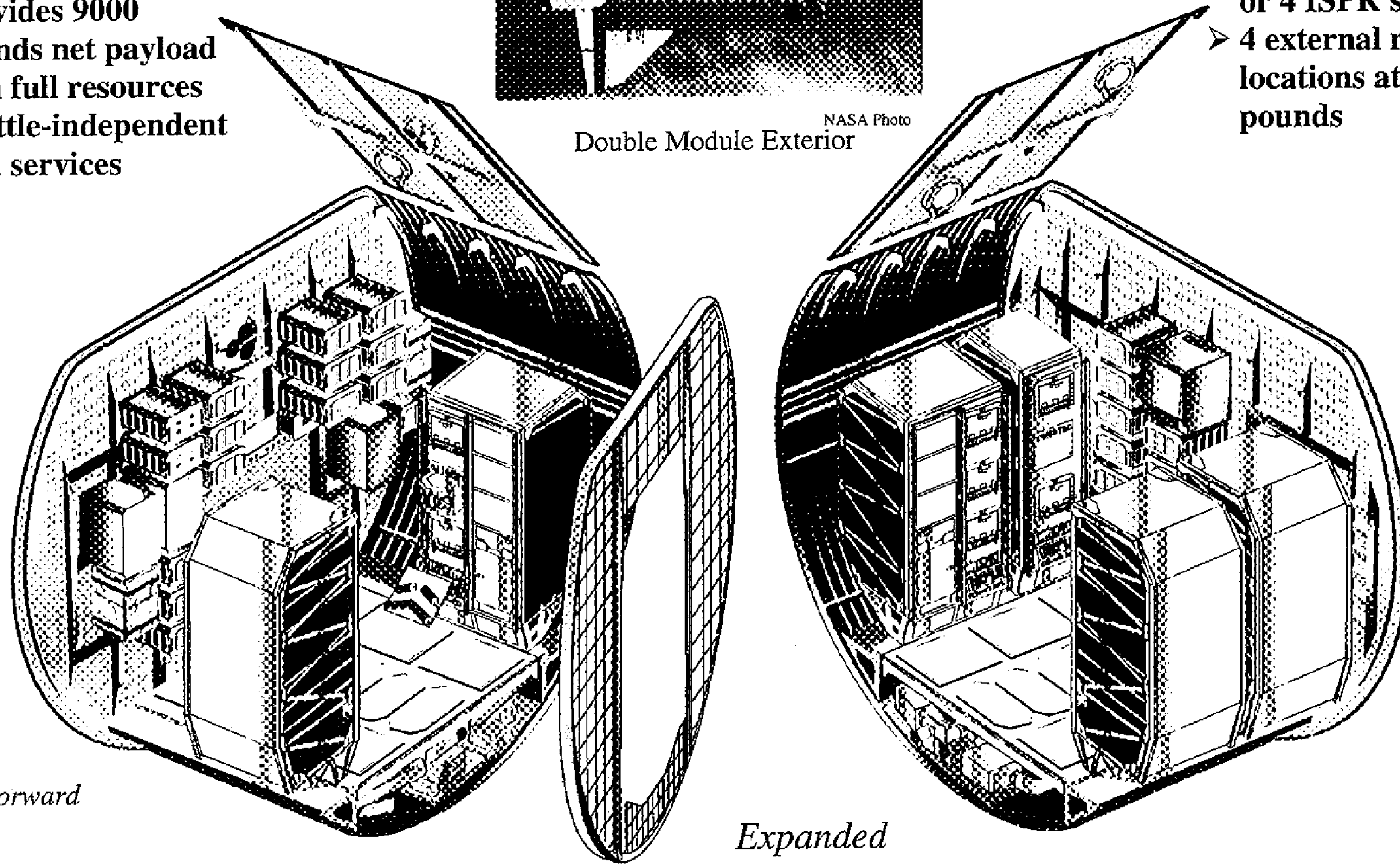
Research Double Module

- Design started in August 1996; first flight on STS-107
- Provides 9000 pounds net payload with full resources
- Shuttle-independent data services



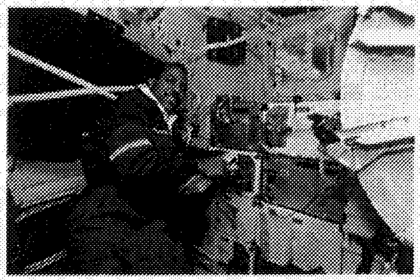
NASA Photo
Double Module Exterior

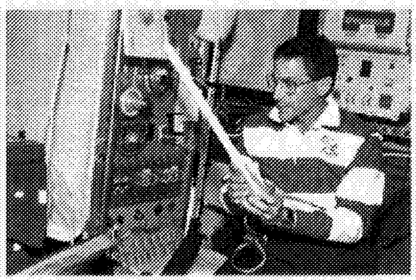
- Lockers flown on both bulkheads
- Can house 6 racks or 4 ISPR's
- 4 external rooftop locations at 500 pounds



Expanded View

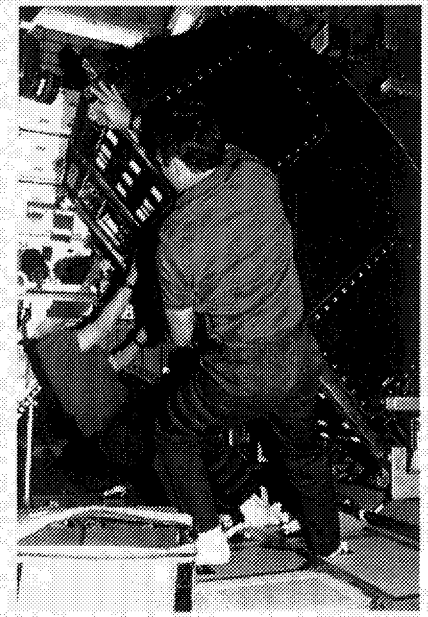
Payload Resources


NASA Photo
Middeck & SPACEHAB Lockers


NASA Photo
SPACEHAB & ISPR Racks


NASA Photo
Viewing out Window(s)

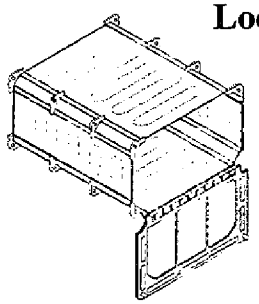
	Single Module	Research Double Module
Weight (lbm) [kg]	4800 [2177]	9000 [4081]
Power - on orbit DC (W) AC (VA)	(2 SMCH) 3150 690	(4 SMCH) 5500 690
Heat Rejection - on orbit (W)	4000	5500
Vacuum Venting	1 Experiment Vent Valve (EVV)	1 EVV forward 1 EVV aft
Data Transfer (NASA)	- low rate PDI (discrete, analog, serial - 25 kbps total) - RS-232 via Serial Converter Units	- low rate PDI (discrete, analog, serial - 25 kbps total) - KuSP channel 2 (2 Mbps total) - KuSP channel 3 (48 Mbps total) - RS-232/422, Ethernet standard - other interfaces by plug-in hardware & software (RAU, 1553) - on orbit record/downlink of LOS data
(Inmarsat)	- 64-256 kbps up/downlink via SHUCS system	- 64-256 kbps up/downlink via SHUCS system
Video Downlink	Video Switch Unit - 8 module inputs - camcorder power - onboard monitors - output to Orbiter CCTV PL input	Video Switch Unit - 8 module inputs - camcorder power - onboard monitors - output to Orbiter CCTV PL input - selectable outputs to video digitizer
Commanding Uplink	- low rate PSP (2 Kbps max.)	- low rate PSP (2 kbps max.) - high rate KuSP channel 1 (128 kbps)
Locker Capability (lkrs)	42 - 62	27 - 61
Rack Capability (racks)	- 2 SH double or single racks - 1 ISPR may sub for a SPACEHAB rack with adapter	- 6 SH double or single racks - 4 ISPR's may sub for SPACEHAB racks with adapter
Refrigerator/Freezer (OSRF)	-20 to 40°C, payload of up to 1.85 ft^3, 40 lb	-20 to 40°C, payload of up to 1.85 ft^3, 40 lb
Viewports (units)	0 - 2	0 - 2


NASA Photo
ARIS ISPR in SPACEHAB

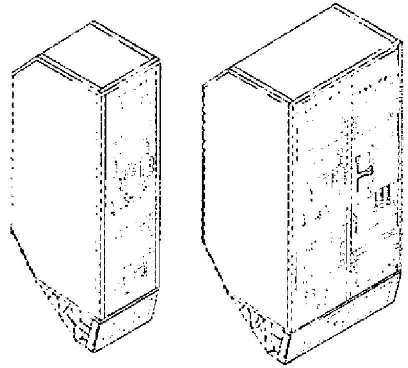

SHI Graphic
External Payloads

Payload Accommodations

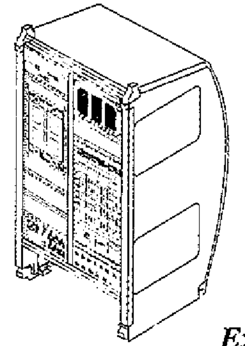
Lockers



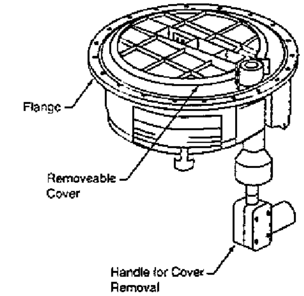
Single & Double Racks



ISPRs

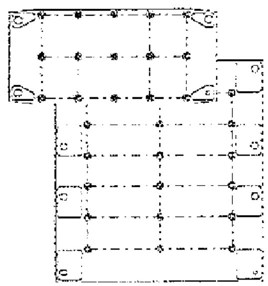


Viewports

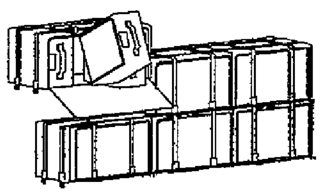


External payloads possible.
Floor mounting in-work (500 lb.)

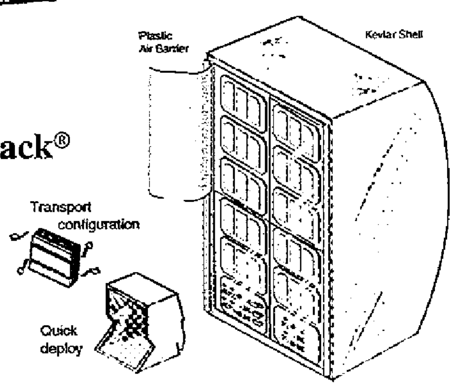
Single, Double Adapter Plates



Soft Stowage® Flight Bags



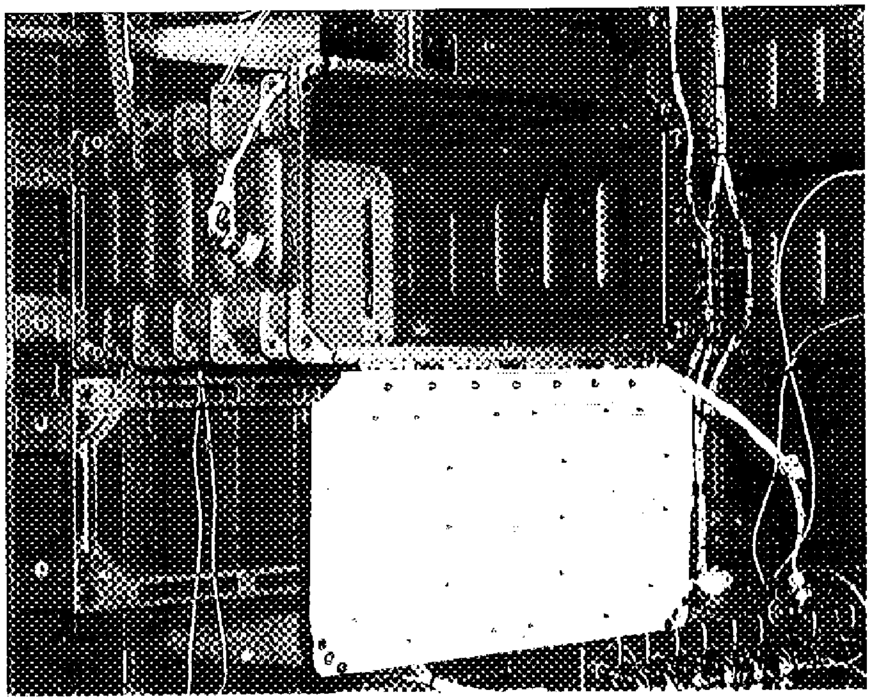
0-G Soft Rack® Concept



	Locker [1, 3]	Single Rack	Double Rack
Weight (lbm) [kg]	60 [2] [27]	655 [2] [297]	1250 [2] [567]
Volume (cu. ft.) [liter]	2 [56]	26 [740]	53 [1500]
Power **AC (VA)** **Ascent, Descent (W)** **DC (W)**	 allocable allocable 115	 allocable allocable 1800 [5]	
Heat Rejection (W)	air cooling	suction air, water cooling interfaces	
Vacuum Venting	available throughout module		
Crew Time (hr)	1 [4]	14 [4]	28 [4]
Data, Commanding	downlink: analog, discrete, serial low-rate data high-rate digital downlink & recording CCTV, NTSC video uplink: serial, pulse discrete commanding		

1 Accommodation in Shuttle Middeck locker(s) possible with similar capabilities.
2 Net payload mass; mass of lockers and racks not included.
3 Resources for Soft Stowage®, plates, and panels same as locker plus mass delta.
4 General allocation; exact value dependent on mission and number of crew shifts.
5 Exact value is mission-dependent; RDM high power location provides 3kW.
6 Soft Stowage® and Soft Rack® are registered trademarks of the McDonnell Douglas Corporation, a wholly-owned subsidiary of the Boeing Company.

Locker Description

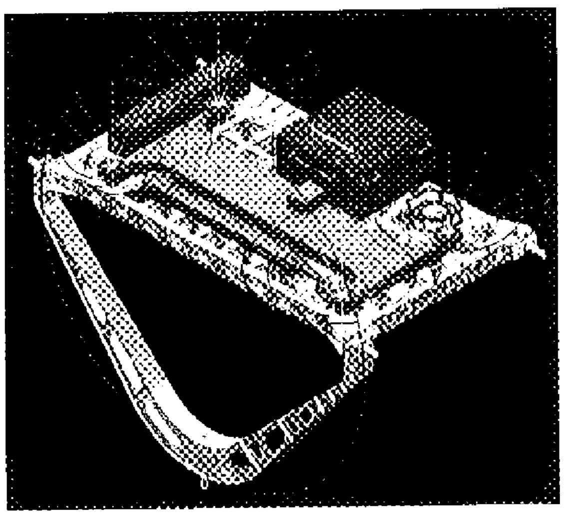


Locker Mounted to Bulkhead

- **Mounts to either forward or aft SPACEHAB module bulkhead**
- **Provides dimensionally-identical interior interface for Middeck payloads**
- **Provides three removable front door panels for use as is, modification, or deletion**
- **Payload support capabilities:**
  - 2 ft^3 (56 liters)
  - 60 pounds (27 kg)
  - 115 W DC power on-orbit
  - Ascent and descent power
  - Air cooling (normally)
  - Various data services
  - Late and early access of contents

External Payloads

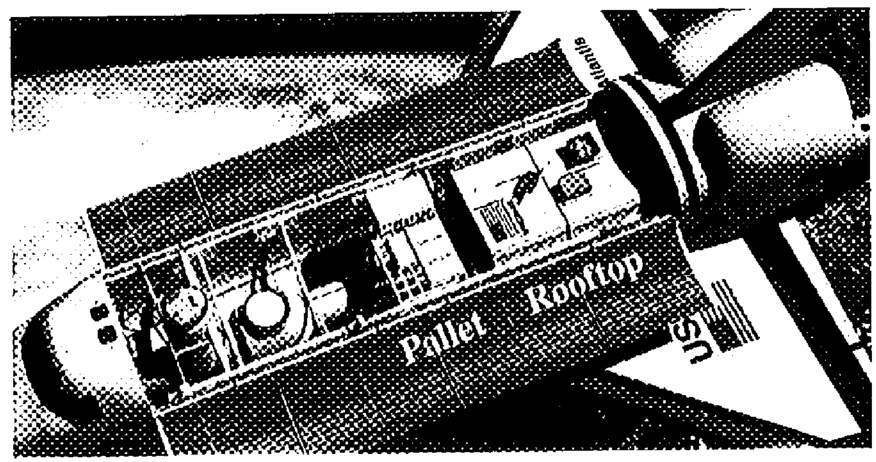
SHUCS Flight Test on STS-91



SOAR Payload on Pallet for STS-101

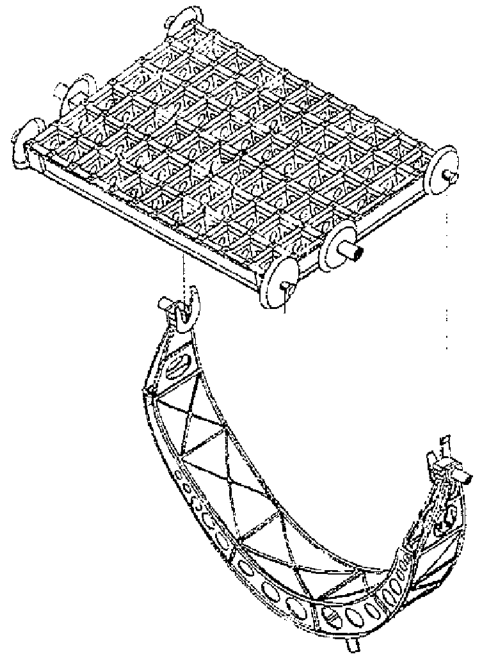
➢ **Full payload support capabilities:**
- 500 pounds at several rooftop locations
- 12,000 pounds on pallet
- Crew operation
- DC power
- Downlink data, uplink commanding
- Active cooling can be developed

➢ **Total capability levels can be driven by customer requirements**

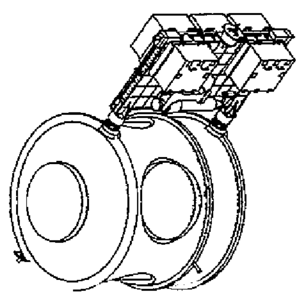


Active and Passive, Cargo and Payloads on Rooftop and Pallet

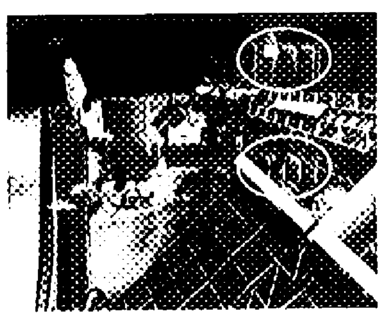
Unpressurized Cargo Pallet



Pallet with Keel Yoke



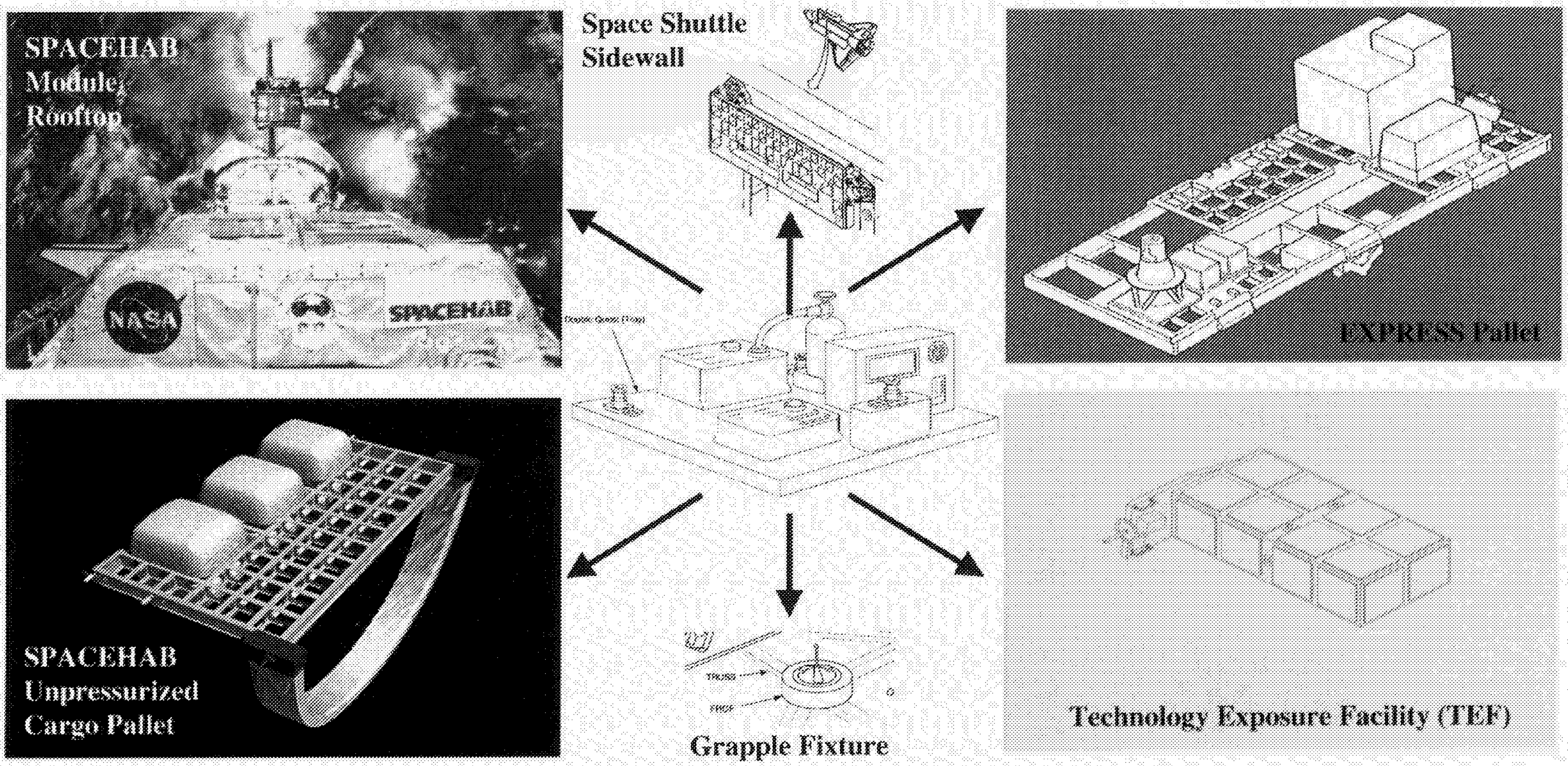
... on Node



... on Truss

- **First pallets nearly complete by DASA and RSC-Energia**
- **First use - STS-96** (May '99)
- **Consists of Keel Yoke and Pallet**
- **Design features:**
  - 12,000 lb. payload capability
  - Cargo mounts to top and bottom of pallet
  - Standard EVA site support
- **Can be manifested**
  - with SH module
  - over tunnel
  - alone
  - with MPLM
- **Future upgrades provide for**
  - standard transport container service
  - active payload support
  - long-term ISS deployment

QUEST Tray

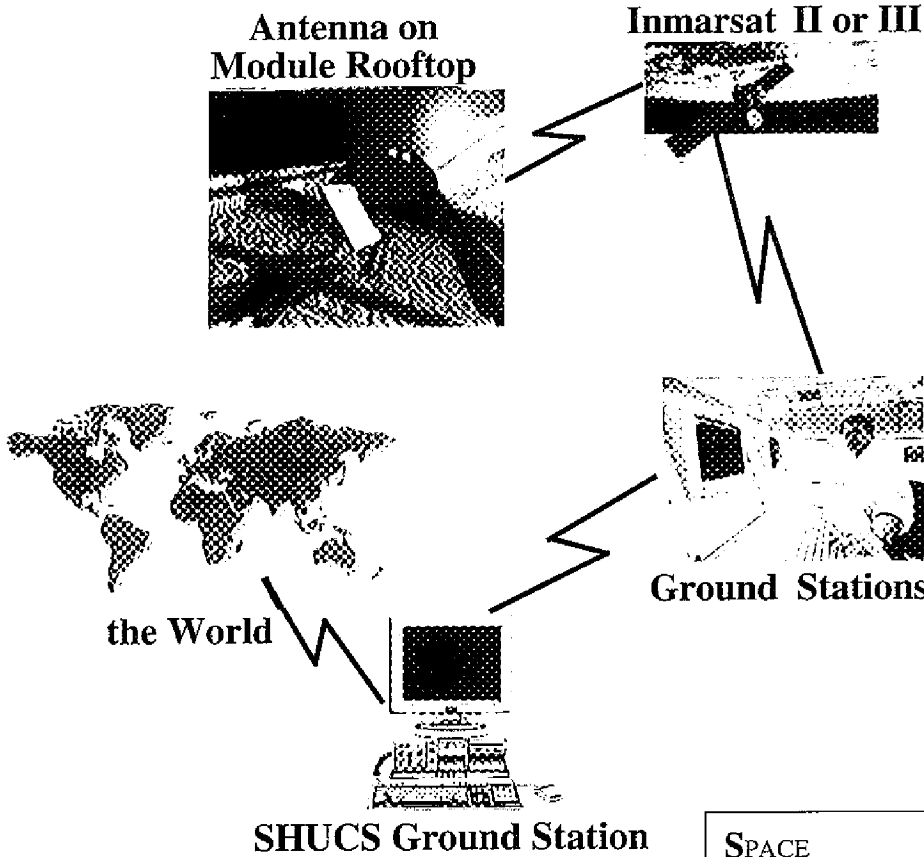


➢**Use of QUEST allows:**
- Standardized external (attached) payload structural interface
- Power, data, and thermal interfaces (Space Shuttle only)
- Payloads to attach in a variety of Shuttle and Station carriers and facilities

QUick
External
Science
Tray

Universal Communications System

Simplified System Schematic

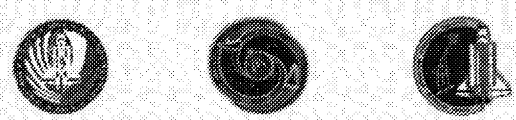


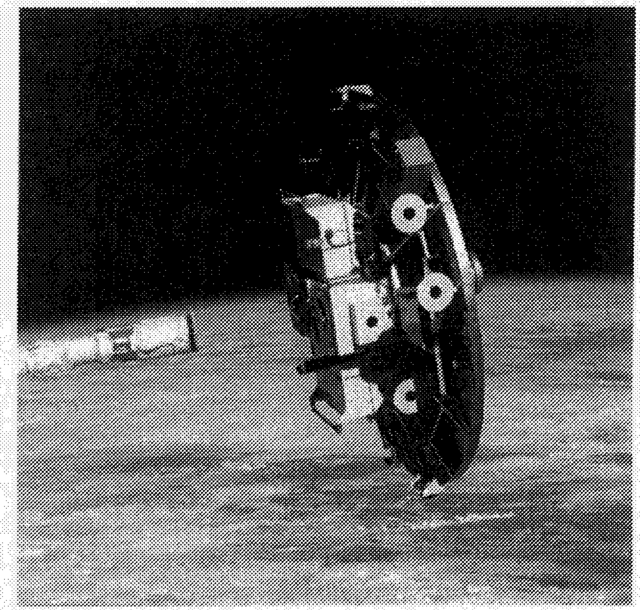
SPACE
HAB
Universal
Communications
System

- **Payload data needs sometimes exceed Shuttle capabilities**
- **SHUCS provides payload-dedicated**
  - audio over "phone"
  - low-rate video
  - data & commands via Internet or direct phone line
  - use of standard commercial hardware and software
- **Using SHUCS**
  - frees up Shuttle data systems for other co-payloads
  - allows research to continue when crew and Shuttle are unavailable
- **Signals sent from module via Inmarsat to ground station and on to customer via phone line or Internet**
- **New Internet extension of .orb**

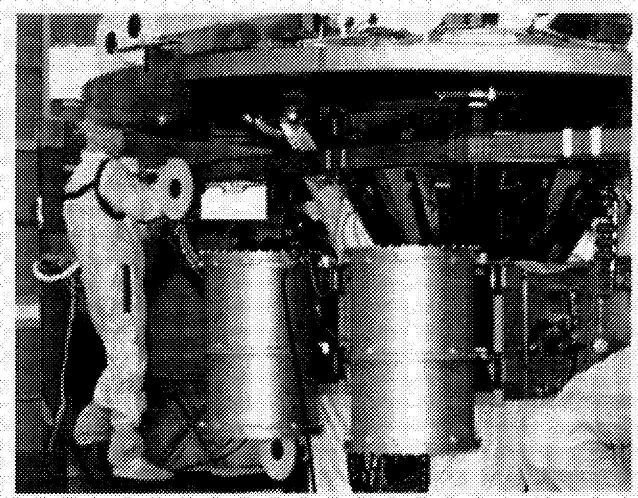
Wake Shield Facility

- **Provides free flyer and Space Shuttle bay payload flight opportunities**
  - High atomic oxygen on free flyer ram side
  - High quality vacuum in free flyer wake
  - Molecular beam epitaxy thin film growth
  - Smart (GAS) cans on base carrier
- **Resources provided:**
  - Independent attitude control (free-flyer)
  - Downlink data, video; uplink commands
  - DC power
  - Environmental monitoring
  - High quality vacuum (free flyer wake)
- **Commercial integration processes:**
  - minimize personnel assignment time
  - minimize documentation required
  - maximize pre-flight time with hardware
- **Three flights have proven hardware**

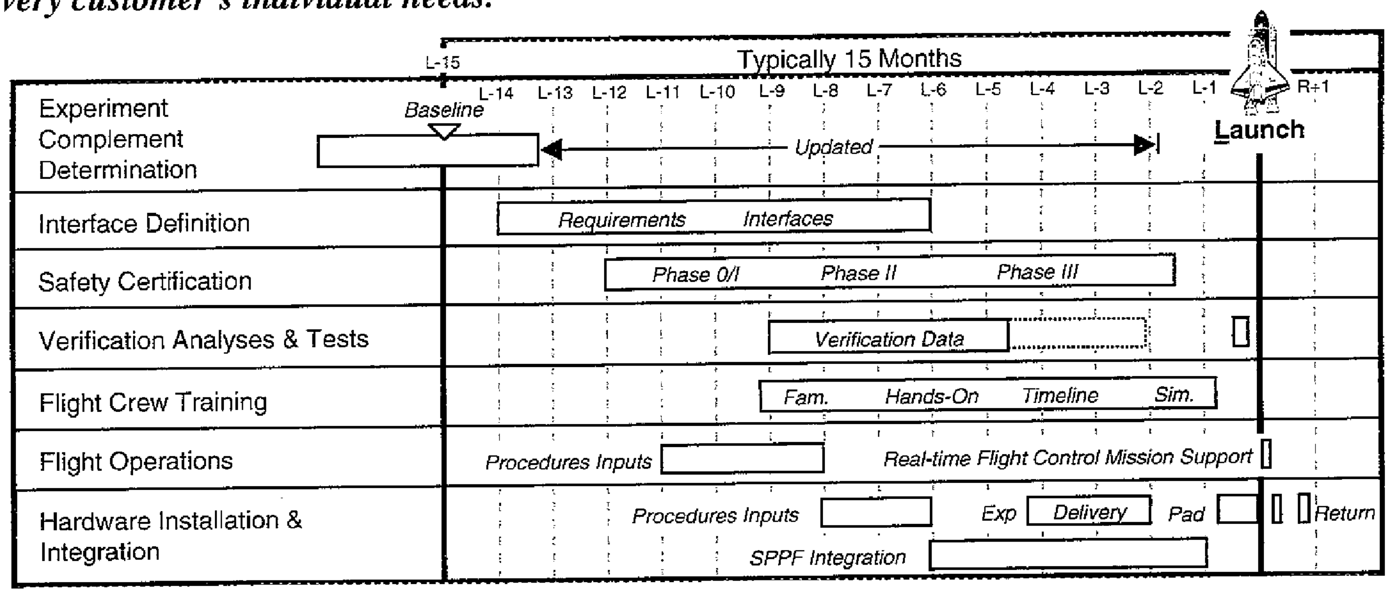




NASA Photos



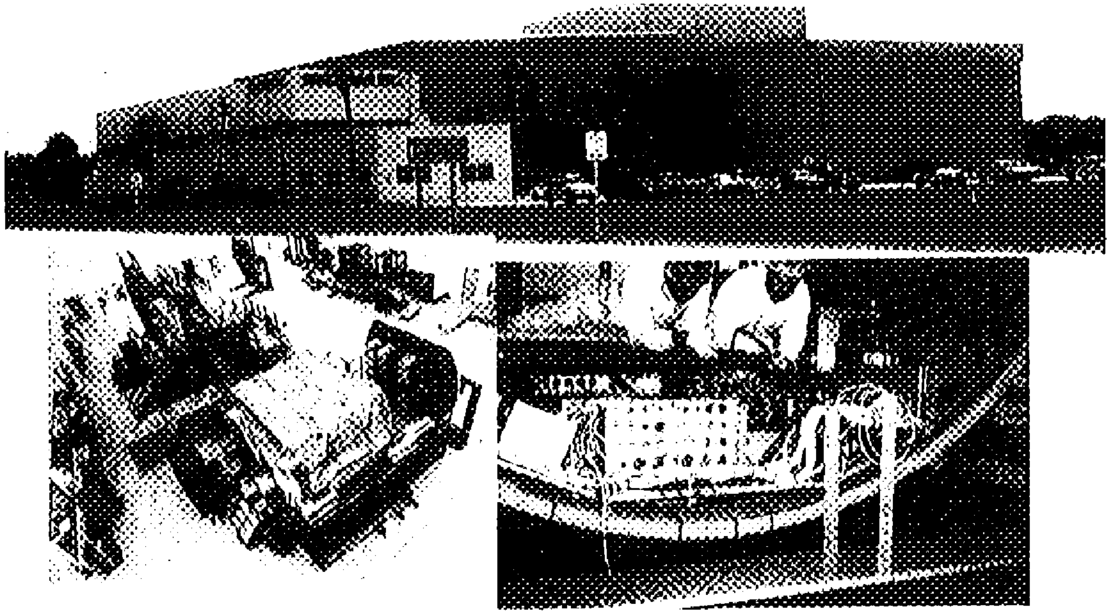
Experienced SPACEHAB team provides a customer-friendly integration process that will be tailored to every customer's individual needs.



➢ Characteristics:

- Single Interface: SPACEHAB provides one point-of-contact for the complete integration process and shields customers from need for detailed knowledge of carrier integration processes.l capability.
- Streamlined Documentation: Information is reused from previous use or other carrier if available.
- Late/Early Access: Significant experiment late access and early retrieval capability.
- Launch Pad Installation: Late module turnover to NASA allows more time with experiment hardware.
- Flexible Approach: Flight-ready payloads have been added as late as 45 days before launch.
- Rapid Reflight: SPACEHAB reflight payloads (same hardware and customer) start at L-8 months.
- Quick Turnaround: Short mission cycle supports commercial experiments.
- Detailed Schedule: Complete mission integration schedules are available at any time for customer use.

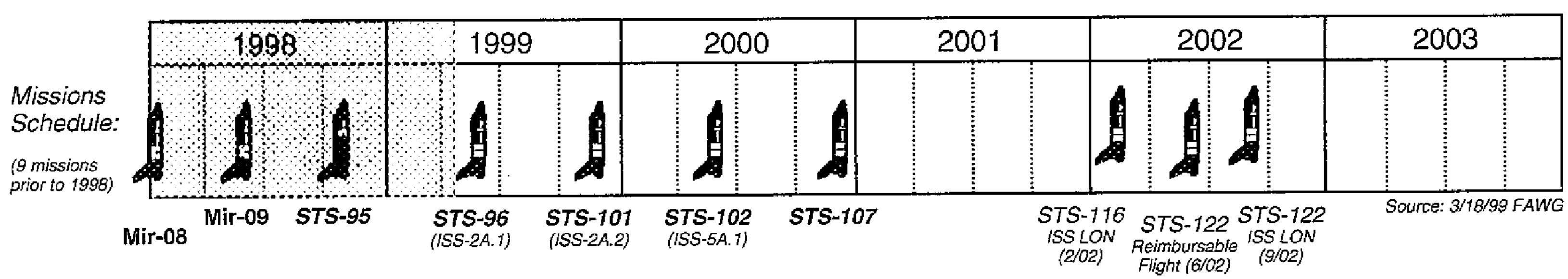
➢ SPACEHAB Payload Processing Facility (SPPF):



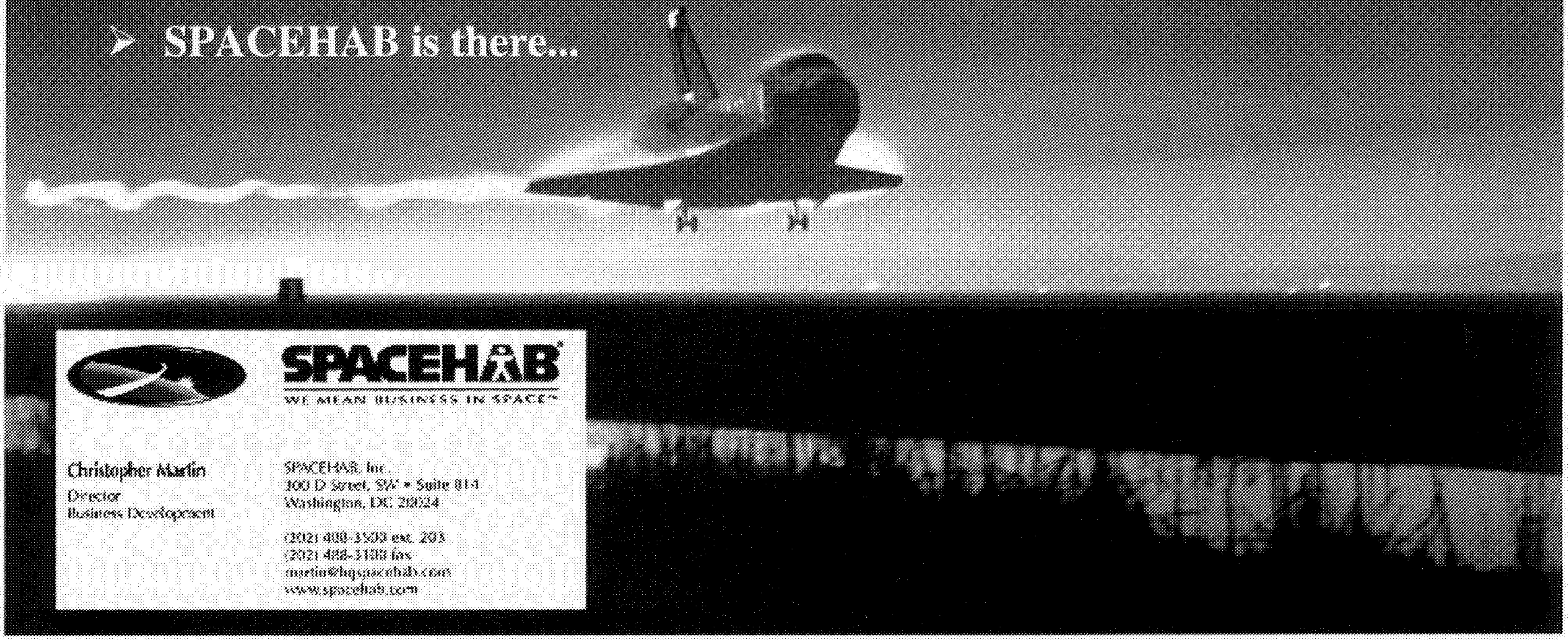
- Located on a commercial site just south of KSC
- 44,500 square feet of payload integration, test, training, & support facilities with more square feet planned
- 11 industrially-secure Customer Work Areas (CWA's) with three more rooms planned
- Clean room conditions - 100K class conditions in CWA's, integration hall, shipping & receiving
- Integration hall accommodates flight modules and training units
- General - conference room, copiers, and fax machine available with new office areas planned

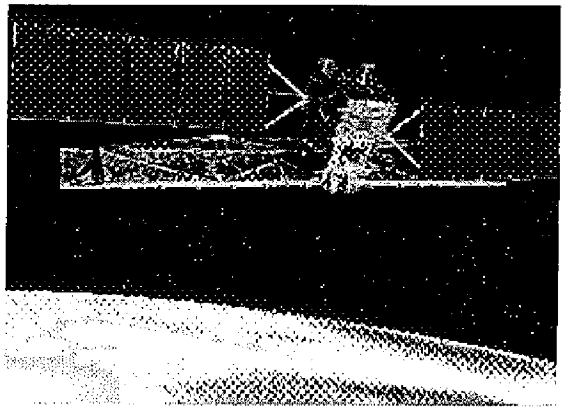
Off-site facility allows streamlined ground safety documentation, payload quality assurance, and international access processes.

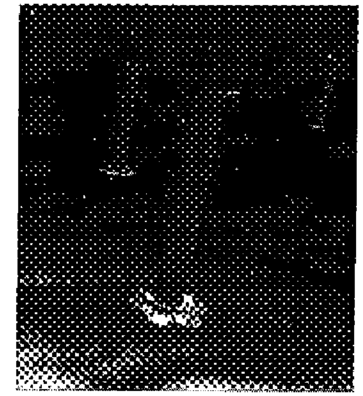
- **Space is available today on STS-107, for flight in late 2000**
- **Process for spaceflight of COTS hardware is understood**
- **SPACEHAB ground and flight services**
  - priced for STS-107 at $29,500 per kilogram for internal payloads
  - available through fixed price contracts (no US government involvement)
  - price includes all aspects of capabilities and integration services described in this presentation
- **Optional services**
  - Assistance with payload hardware adaptation for spaceflight
  - Assistance with payload safety and verification documentation
- **Pricing for optional services can be made available on request**
- **Flight schedule:**



- SPACEHAB, Inc. has a proven record in commercial human space.
- We look forward to working with the NRO team towards the spaceflight of payloads on SPACEHAB.
- The Space Station era has begun, and
- SPACEHAB is there...

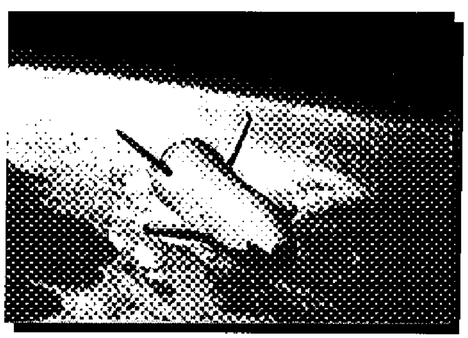




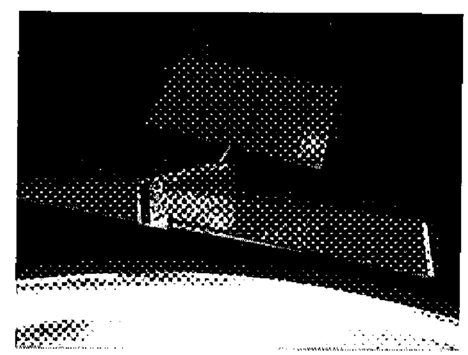


The nanoSat Payload Ejection System

Steven Huybrechts
Space Vehicle Technologies Branch



Space Vehicles Directorate
Air Force Research Laboratory
Kirtland AFB, New Mexico

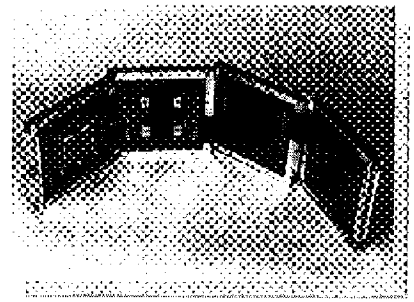


Overview
Space Vehicle Technologies Branch

Vision

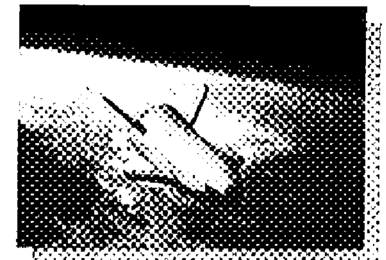
Revolutionize
Space Vehicle Technology
to Meet
Future Warfighter Requirements

Structures



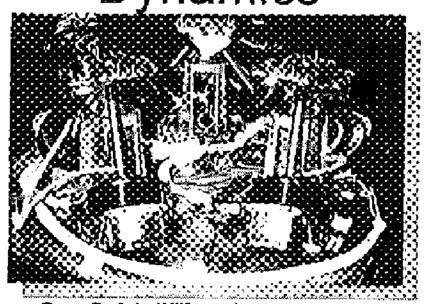
Multifunctional Structures

SMV



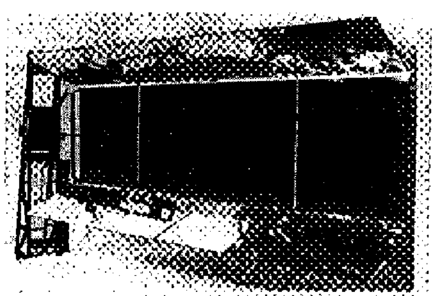
Maneuvering Space Vehicles

Dynamics



On-Orbit Vibration Isolation

Power &
Thermal

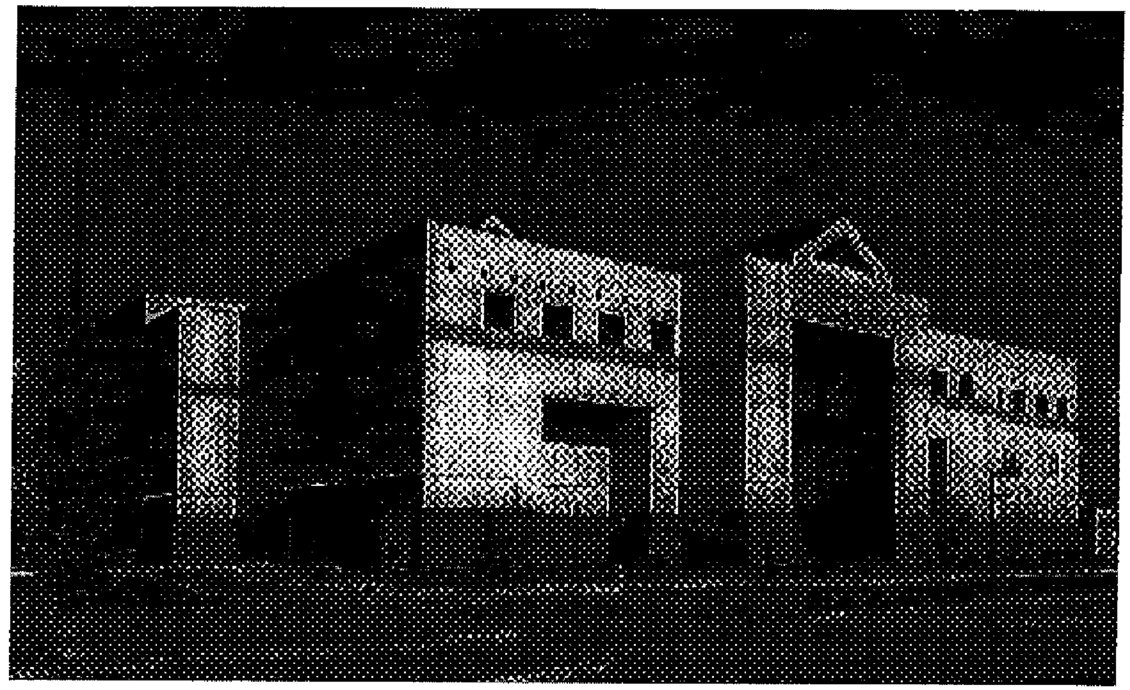


High Total Power Solar Generation

Mission

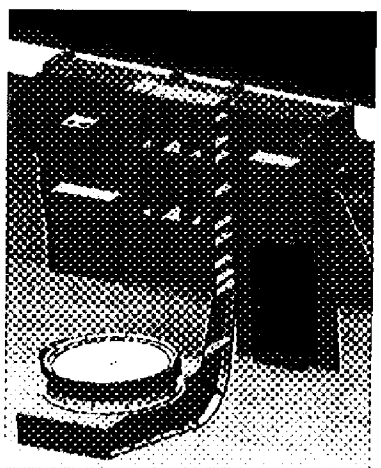
Conduct
Innovative Space Vehicle Research,
Development, and Transition
of
Advanced Power, Thermal Management,
Structures, and Controls Technology
to
Support Global Engagement

Facilities
Space Vehicle Technologies Branch



- Composite Lab
  - Filament Winding
  - Pultrusion
  - Carbon-Carbon
  - CT-Scanning
  - Mechanical Testing
- Acoustics Lab
- Energy Generation Lab
- Energy Storage Lab
- Thermal Research Lab
- Large Deployable Structures Area
- Precision Structures Lab
- Active Controls Lab
- Isolated Controls Facility

The University nanoSat Program



Leverage

Innovating Thinking at U.S. Universities

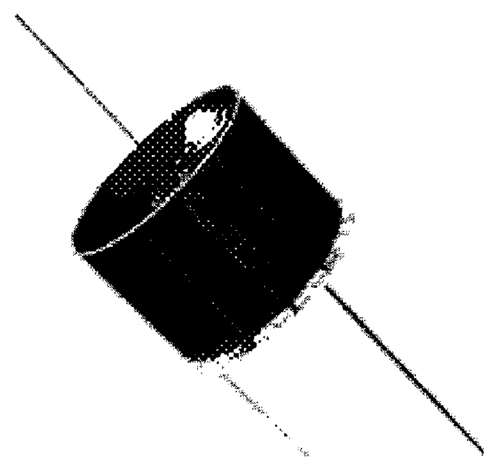
Demonstrate

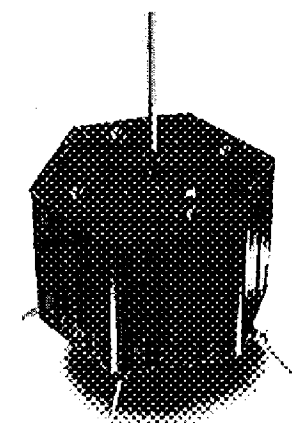
Nanosat Technologies &

Advanced Mission Concepts

Technologies of Interest

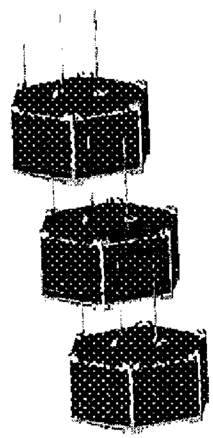
Formation Flying
Miniaturized Sensors
Micro-Propulsion
Guidance & Navigation
Multifunctionality
Collaborative Processing

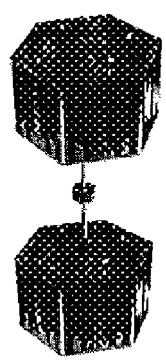


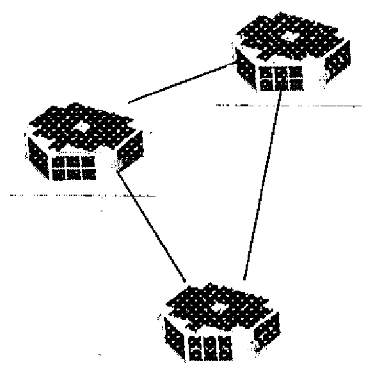


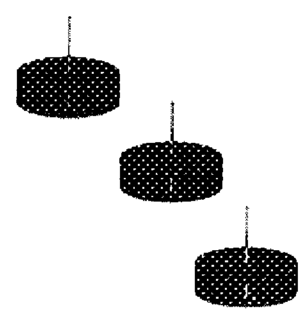
Program Participants

Program	Institution	Principal Investigator
Three Corner Sat	Arizona State U	Reed
Three Corner Sat	U of Colorado at Boulder	Hansen
Three Corner Sat	New Mexico State U	Horan
Emerald	Stanford U	Twiggs
Emerald	Santa Clara U	Kitts
ION-F	Utah State U	Redd
ION-F	U Washington	Campbell
ION-F	Virginia Tech U	Hall
Solar Blade Nanosat	Carnegie Mellon U	Whittaker
Constellation Pathfinder	Boston U	Spence


3-Corner Sat


Emerald


ION-F


Constellation Pathfinder

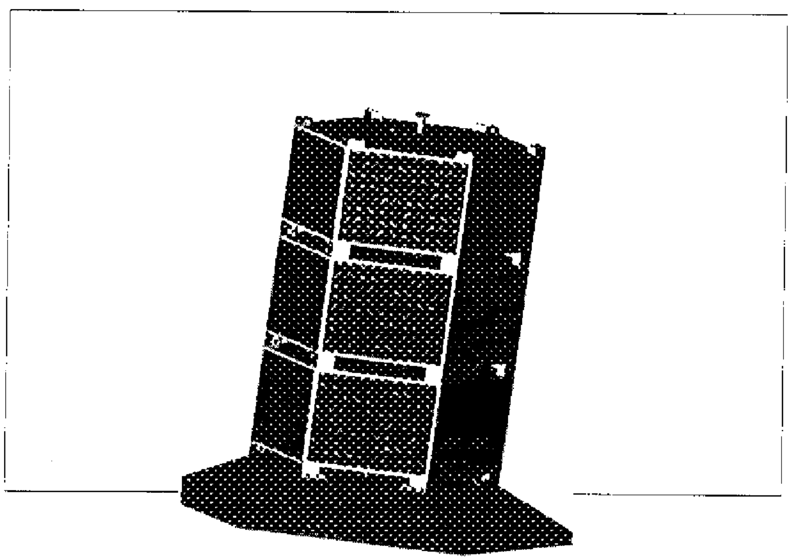

Solar Blade NanoSat

Three Corner Sat Constellation

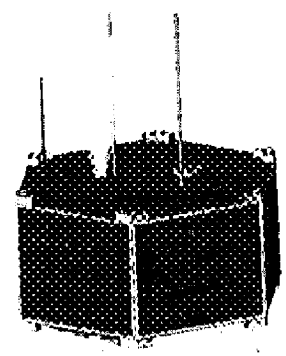
Arizona State, New Mexico State, University of Colorado

Constellation of Three Identical nanoSats

Stereo Imaging
Formation Flying
Cellular Phone Communications
Innovative Command and Data Handling



Launch



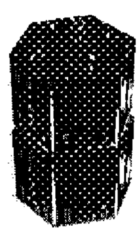
On-Orbit

The Emerald Mission

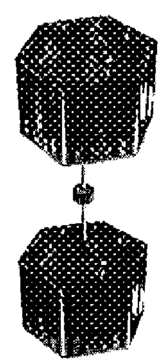
Stanford & Santa Clara University

Validation of Spacecraft Formation Flying Technologies

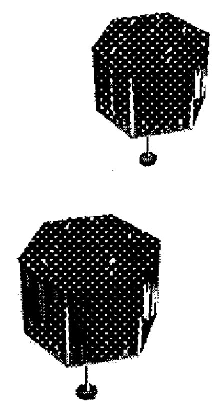
GPS Based Relative Position Sensing
Direct Intersatellite Communications
Position Control Using Tether, Drag Panels, & Colloid Microthrusters
Formation Flying Through a Distributed Ionospheric Science Exp



Stacked



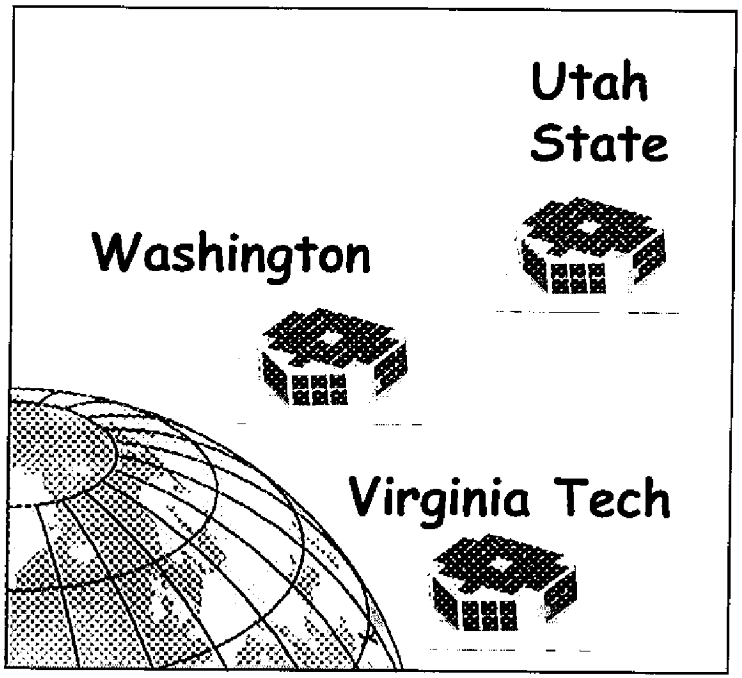
Tethered



Separated

Ionospheric Observation nanoSat Formation

Distributed System Science & Cutting Edge Technologies



Formation Flying & Management

Inter-Satellite Cross-Links

Distributed Ionospheric Data

Small Satellite Subsystems

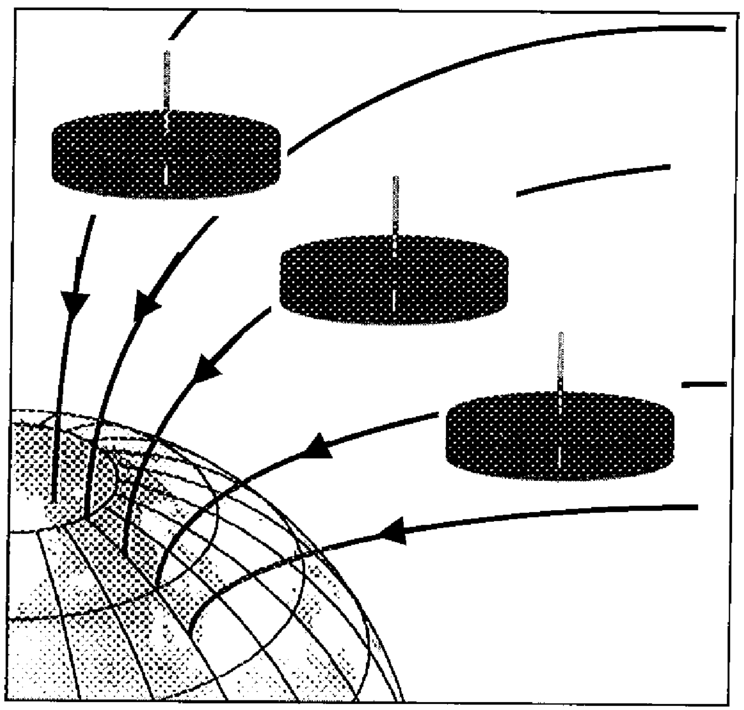
Internet Control of a Distributed Space System

Constellation Pathfinder

Boston University & Draper

1kg, 1W Nanosats Capable of Returning
High-quality, 3-pt Vector Magnetic Field Measurements

Pathfinder for a 100-200 nanoSat Mission to Map the Dynamic Magneto-Sphere for Robust Prediction of Space Weather



Autonomous Spin-Stabilization

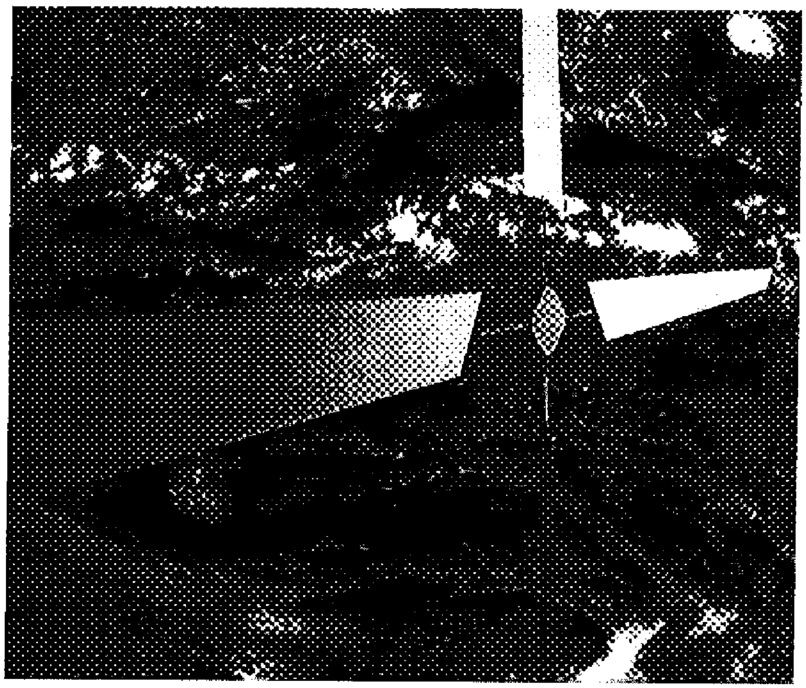
Measurement of Low Level DC Magnetic Fields

Launched From "Mother Ship" Providing a Central Point for InterSatellite Communication

Solar Blade nanoSat Solar Sail

Carnegie Mellon University

Demonstrate HelioGyro Solar Sail Technology



Attitude Control

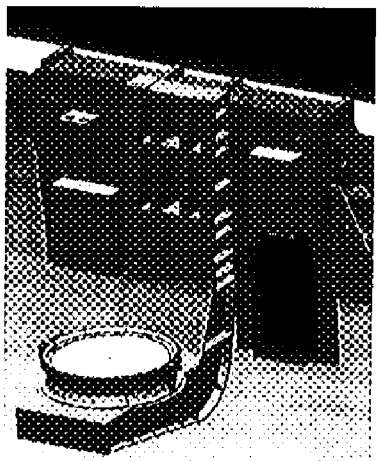
Position Changes

Spiral Out Past the Moon

Collective & Cyclic Pitching of 20m Blades Creates Propulsion from Photon Pressure

The nanoSat Payload Ejection System

Provide Low-Cost Launch Opportunity for University nanoSats



Goal: Flexible, Reusable Design

Preferred Option: OSP/Pegasus

Higher Cost

All nanoSats Launch Together

Minimal Ejection System

Desirable Orbit

Backup Option: Shuttle 'SHELS' System

Lower Cost

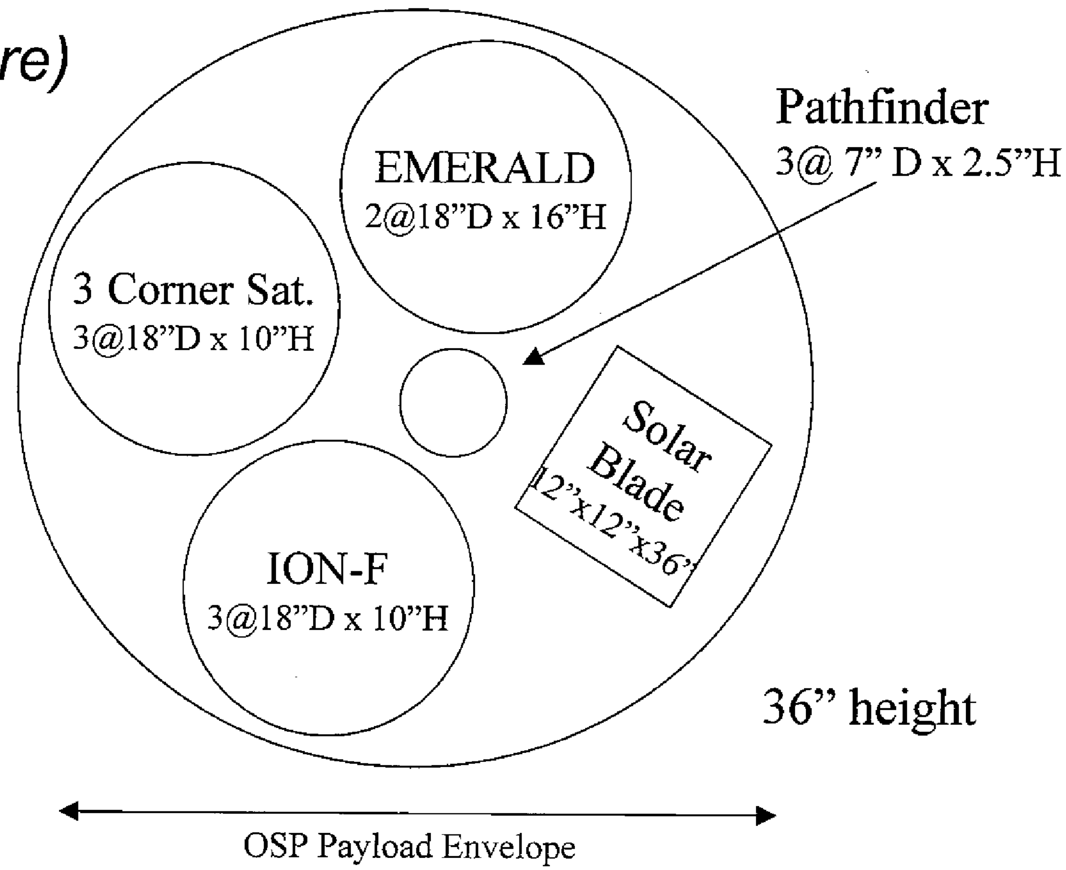
Requires 2 Separate Launches

Increased Ejection System Complexity

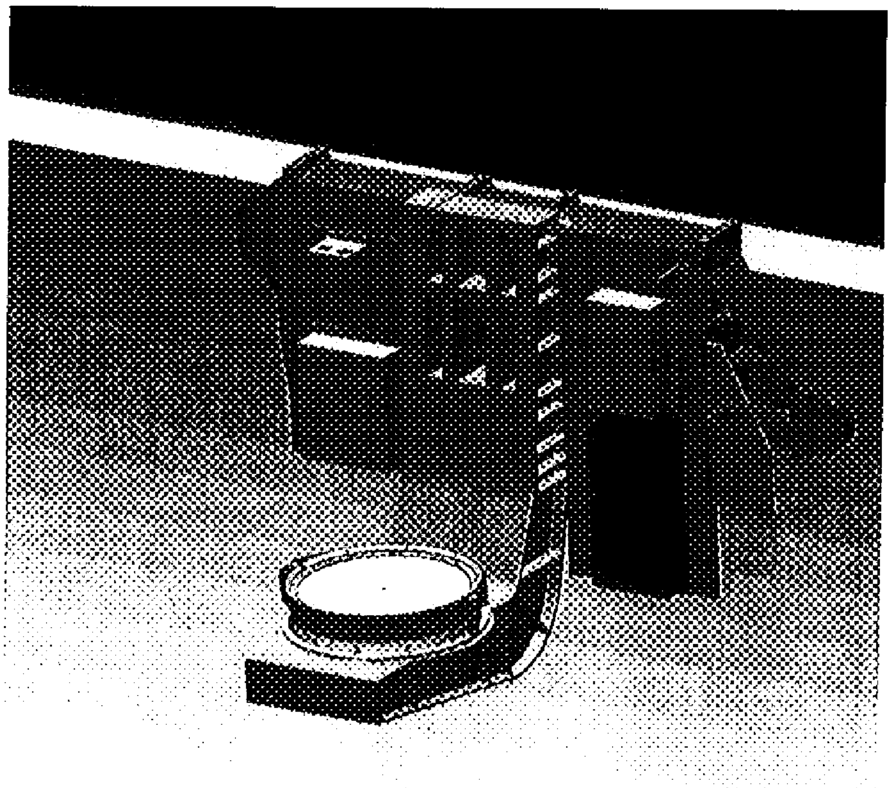
Solar Blade Dropped

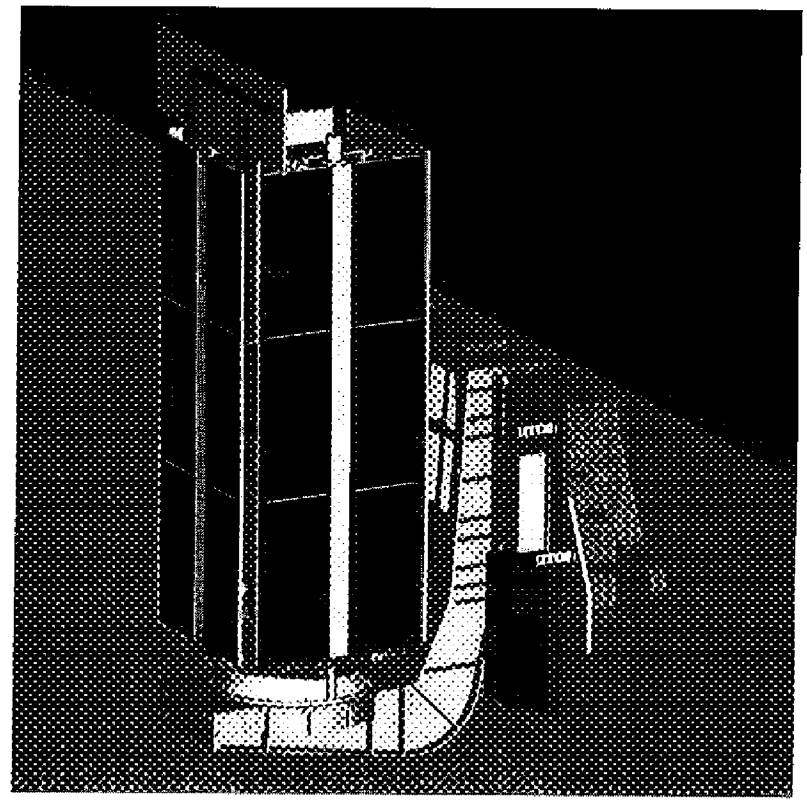
Pegasus or OSP Layout

Total Mass
(With Support Structure)
225 kg

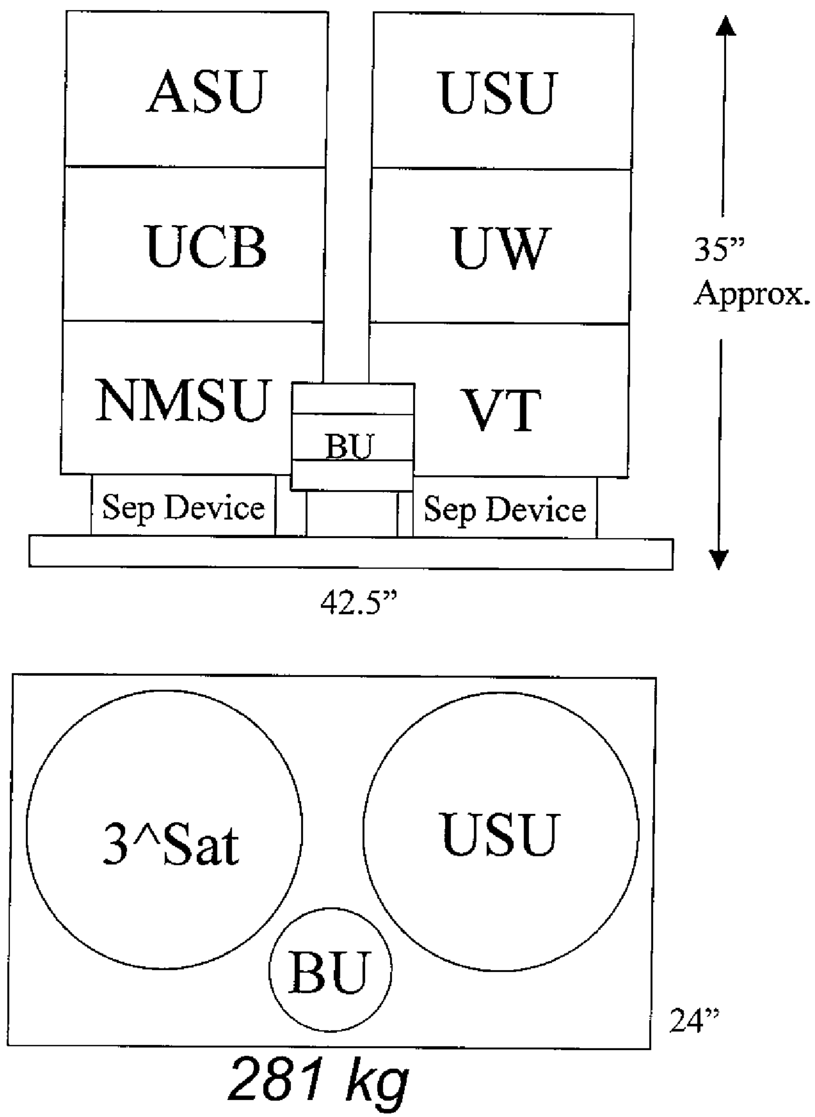


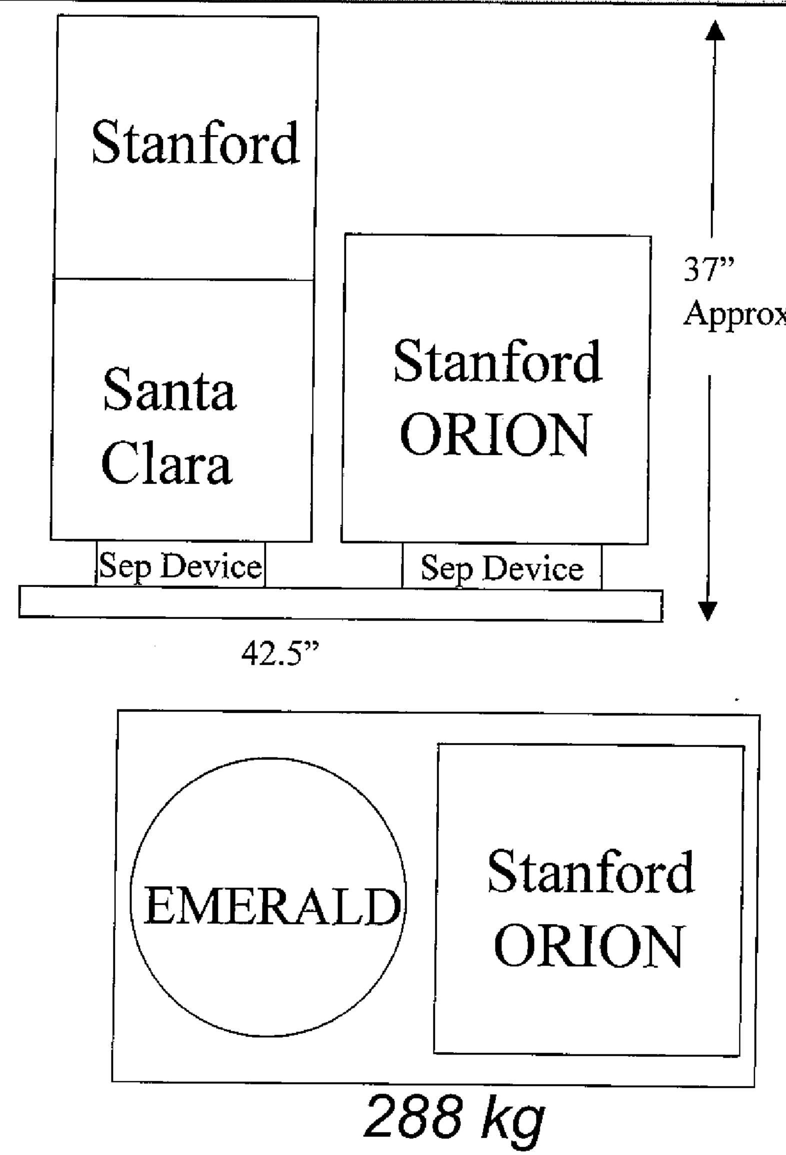
Shuttle Hitchhiker Experiment Launch System (SHELS)





Shuttle Hitchhiker Experiment
Launch System Layout





Conclusions

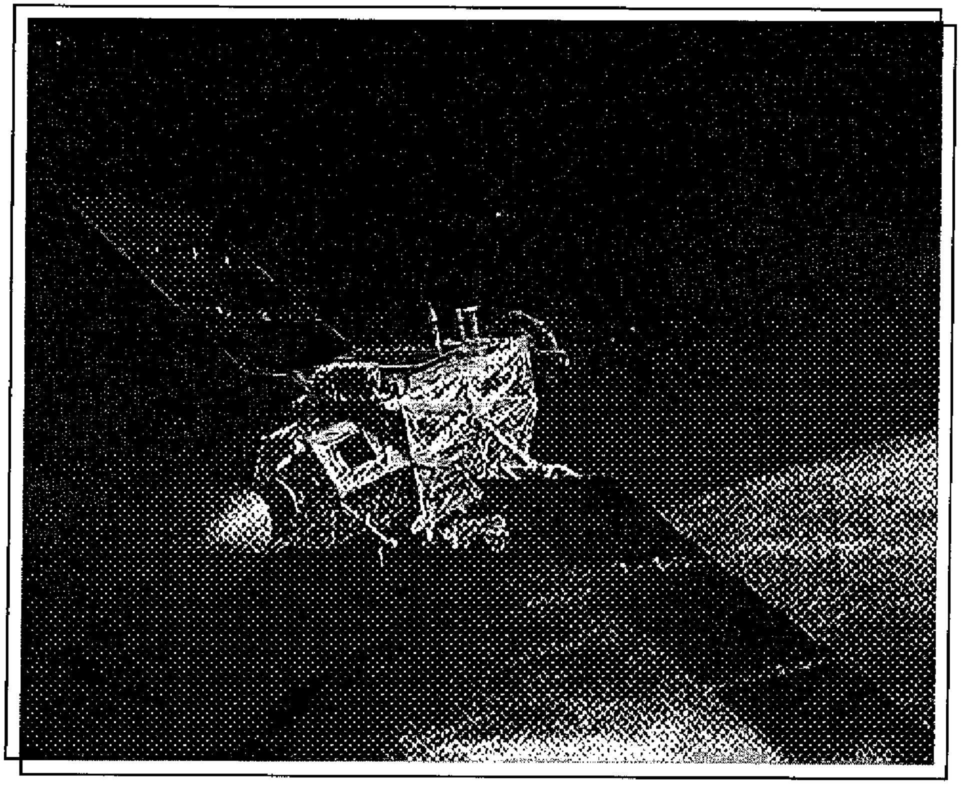
Mulitiple & Varied
Technology Demonstrations
Scientific Measurements

Significant Payoff for Minimal Funding

Follow-on Launches Likely

Industry/Government Partners
Encouraged to Participate

Space Test Program (STP)



RideShare Conference
16 Apr 99

Maj Michael Ward
SAF/AQSL
703-588-7376

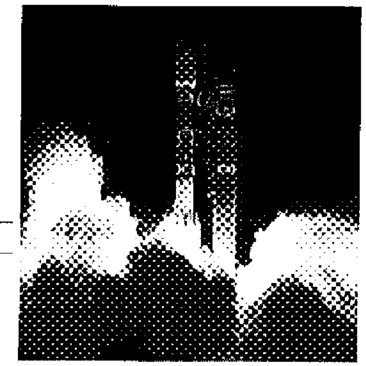
Space Test Program
Outline

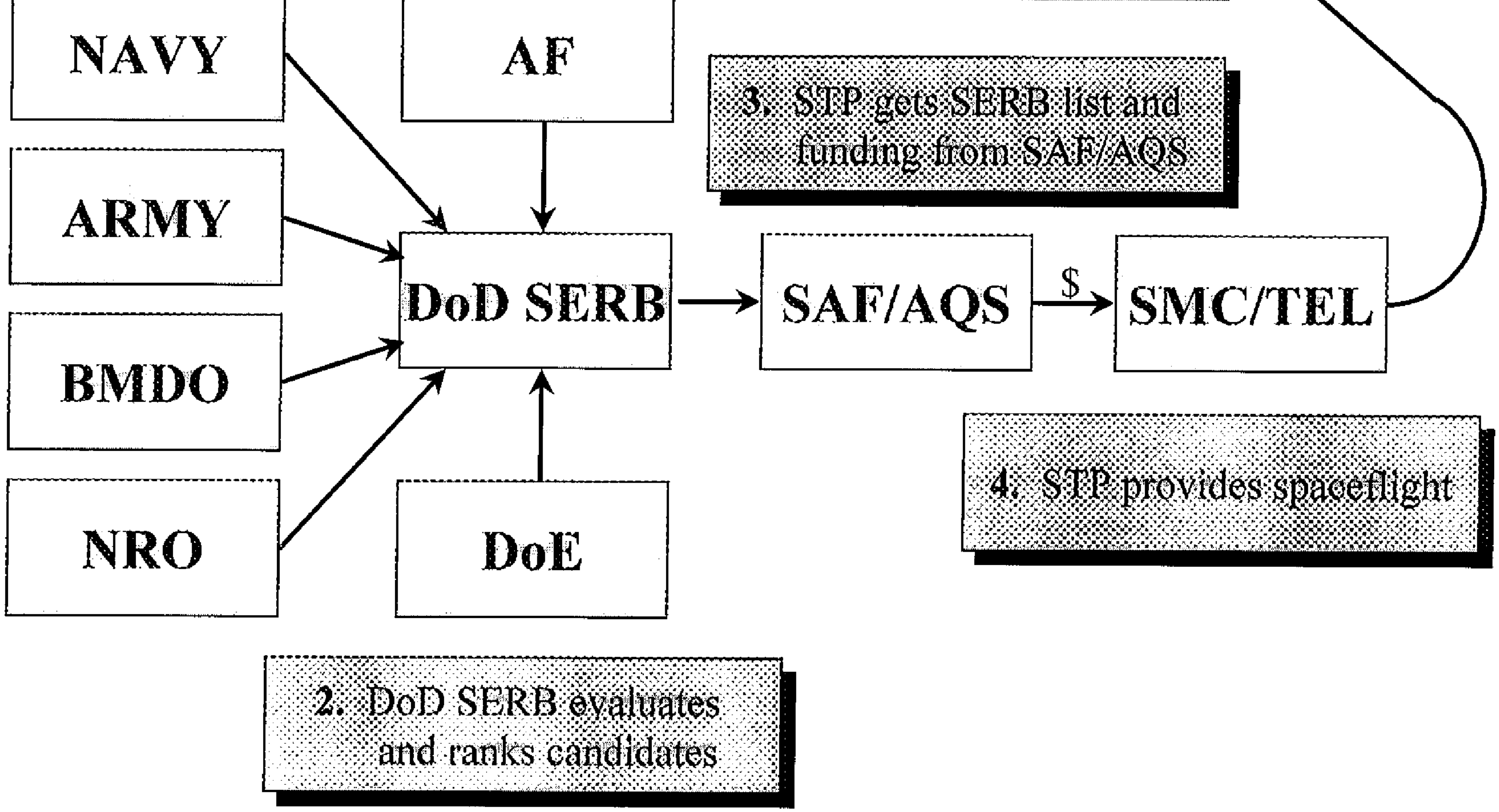
- ❑ Program Description
- ❑ SERB Process
- ❑ Recent Missions Flown

Space Test Program Description

- Provide spaceflight and on-orbit operations for highest priority DoD space experiments, based on rankings of annual DoD Space Experiments Review Board (SERB)
  - SECDEF letter (6 Nov 95) reaffirmed this STP mission
  - STP does not fund or provide the space experiments
- STP investment pays dividends in demonstrating new space technologies for military and commercial applications
  - STP demonstrated key technologies and flew prototype for the GPS constellation
  - STP demonstrated operational capabilities of advanced comm technologies (EHF spread spectrum, K band) used in Milstar, DSCS III, TDRSS
- To date, STP has flown 426 experiments on 135 missions since 1967. Of these, 113 missions have been successful (84% success rate.)

Space Test Program
SERB Process





Space Test Program
1999 SERB

¥ Held 13-15 Apr 99 @ ANSER facilities, Arlington, VA

¥ 43 candidates addressed the following technology areas:

—Communications

—Threat Warning

—Surveillance

—Microsatellites

—Subsystem Improvements

—Space Weather/Environmental Monitoring

¥ See website at http://www.safaq.hq.af.mil/aqsl/spacetest

- Get a DoD sponsor, usually a lab or systems center
- Fill out 1721 paperwork (request for spaceflight)
- Meet Service-level SERB prior to DoD SERB
- Meet DoD SERB in Nov 00

Space Test Program
Recent Missions Flown

- **STS-95 29 Oct 98 from KSC**
  - NPS-901 (Mission S94-D) Petite Amateur Navy Satellite (PANSAT)
  - NRL-704 Be-7 Measurement in Low Earth Orbit (WAKEBE/TASBE)
  - PL-504 (Mission S96-4) 60 Kelvin Thermal Storage Unit (CRYOTSU)
  - ASPWS-701 Cell Culture Module (CCM)

- **STS-88 4 Dec 98 from KSC**
  - NRL-402 Shuttle Ionospheric Modification with Pulsed Localized Exhaust (SIMPLEX)
  - PL-606 MightySat-1 (Mission P97-1)

- **ARGOS freeflyer on Delta II (P91-1) 23 Feb 99 from VAFB**
  - AL-601 Electric Propulsion Space Experiment (ESEX)
  - ECOM-501 Extreme Ultraviolet Imaging Photometer (EUVIP)
  - GL-806 Critical Ionization Velocity (CIV)
  - NRL-206 High Temperature Superconductivity Space Experiment (HTSSE II)
  - NRL-304 High Resolution Airglow/Aurora Spectrometer (HIRAAS)
  - NRL-505 Coherent Electromagnetic Radio Tomography (CERTO)
  - NRL-701 Global Imaging Monitor of the Ionosphere (GIMI)
  - NRL-801 Unconventional Stellar Aspect (USA)
  - ONR-502 Space Dust Experiment (SPADUS)

EELV Secondary Payload Adapter (ESPA)

Capt Scott A. Haskett
USAF Space Test Program
SMC/TELO
(505) 846-8570

Overview

- ESPA Motivation
  - Small Satellite (SmallSat) Uses
  - US SmallSat Launch Capabilities
- ESPA Program
  - Characteristics and Capabilities
  - Current Activities/Far-Term Plan
  - ESPA Customers
- Conclusion

Small Satellites (<200 kg)

- Space Experiments
  - Inexpensive Way to Demonstrate New Space Technology
  - Perform Space Experiments
  - Test Operational Prototype Hardware
- AFSPC Researching Operational Missions for Smallsats
  - Space-Based Radar, Space Support

US SmallSat Launch Capabilities

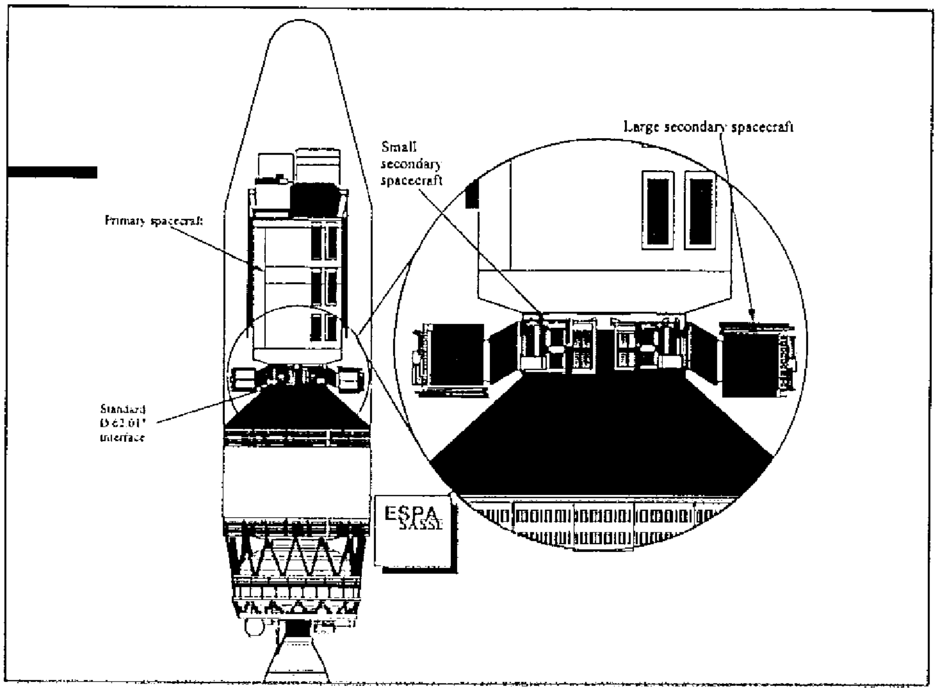
- US Medium/Heavy ELVs Have No Built-in Secondary Payload Capabilities
  - Secondary launches are "custom" missions
- Cheapest US Booster: OSP
  - Orbital/Suborbital Program (OSP) uses Minuteman II, Pegasus XL stages
  - Dual-Satellite launch on OSP costs ~$14M
- Least Expensive SmallSat Launch Today Costs $7M

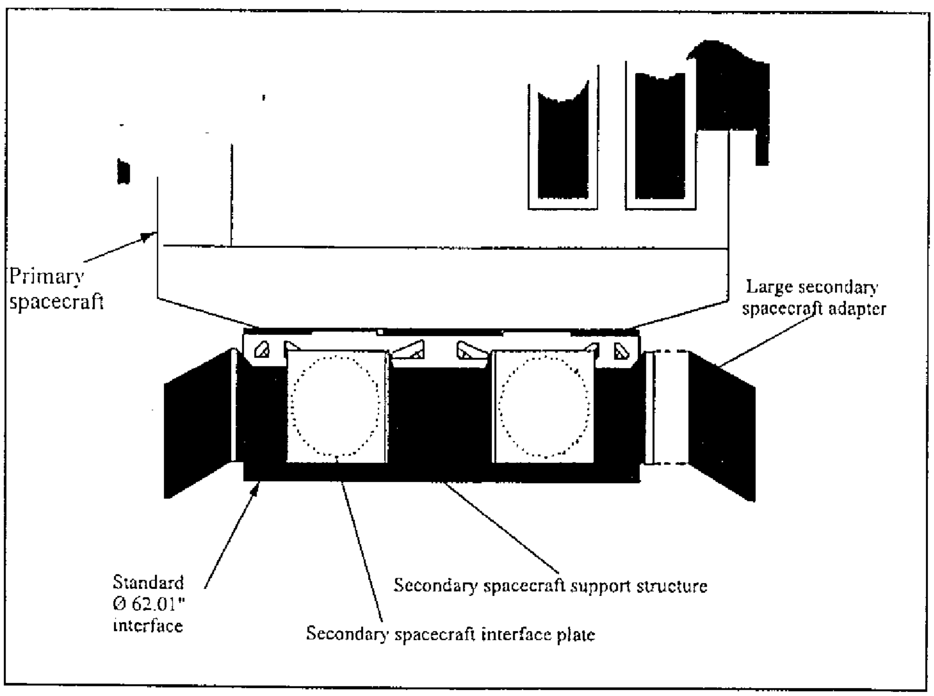
EELV

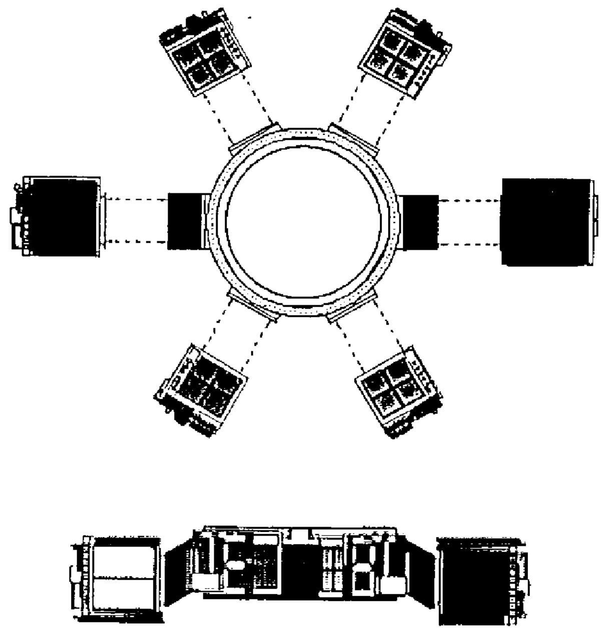
- EELV Launchers Are Very Capable
  - At least 58% of manifested DoD EELV Medium Missions have >2000lbs margin
- EELV Has No Requirement for Secondary Payloads
- ESPA Uses EELV Margin to Launch up to Six SmallSats in Addition to the Primary Payload

ESPA Characteristics

- Cylindrical Structure, 24" tall
- Est. Empty Mass: 114 kg (250 lbs)
- Holds Six SmallSats + Primary Payload
  - SmallSats: 30-inch cube, up to 220 lbs
  - ESPA projected maximum: 910 kg (2000 lbs) "fully loaded"
- Design Allows Secondary Separation Before Primary Separation (if needed)


Large secondary spacecraft
Small secondary spacecraft
Primary spacecraft
Standard
Ø 62.01"
interface
ESPA


Primary spacecraft
Large secondary spacecraft adapter
Standard
Ø 62.01"
interface
Secondary spacecraft support structure
Secondary spacecraft interface plate



ESPA Impacts to Primary

- Negative:
  - Raises Primary Payload 24"
    - Reduces Usable Volume in Fairing
    - Raises CG
  - Effects can be Minimized by Optimizing Primary Payload Adapter
- Neutral:
  - Design Replicates EELV Standard Interface Plane to Primary

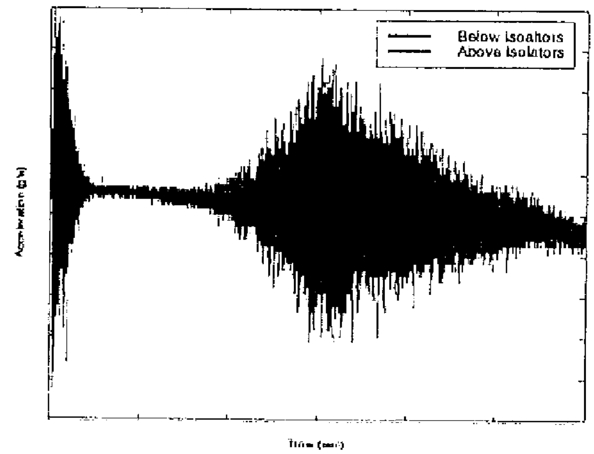
ESPA Impacts (continued)

- Neutral (continued):
  - Minimum Interaction between Primary and Secondaries
  - Shockless/Non-Pyro Separation Systems for Secondaries
- Positive:
  - Greater Payload Mass Reduces Vibration of Payload Stack
  - *Vibration Isolation (Soft Ride)*

Vibration Isolation

- Reduces Dynamic Response of Secondary Equipment by at Least a Factor of 2
  - Secondaries have separate isolation systems also
- Proven Technology
  - Taurus: GFO (~60% isolation)
  - Taurus: STEX (~85% isolation)
  - OSP Flight 1 (Scheduled September 99)

Isolation on GFO



ESPA Program Details

- Joint STP-AFRL/VSD Program
  - Estimated Non-Recurring Cost: $4.4M
- ESPA Special Study Initiated by EELV SPO April 99
- AFRL Will Build One Qualification Model, One Flight Model
  - PDR June 99, CDR June 00
- IOC FY02; Hoping for Launch in FY 03
  - DMSP, GPS, SBR

ESPA Flight 1

- STP Budgeting for First Flight Integration Costs
  - Cost-sharing anticipated for any non-STP payloads
- Mission Guidelines
  - Secondary Manifest Managed by STP
  - Secondaries delivered on time or don't fly
  - Primary Drives Umbilical Connections
  - Secondaries "Dead" Until Release

Far-Term ESPA Plan

- STP Researching Cooperative Agreement with EELV Prime Contractors
  - Primes procure ESPA, making it optional on any DoD EELV Medium mission
  - ESPA available to commercial market
- Secondary Manifest Managed by Primary ESPA Customer (e.g. NASA, STP) or Third Party (e.g. USRA)

Estimated Recurring Costs

- ESPA Cost: $700,000 to $900,000
  - $600,000 for ESPA cylinder & primary isolation system
  - $50,000 per secondary isolation system
- Estimated Integration Costs: $1.0M
- ESPA Goal: Keep Cost per Satellite (fully-loaded ESPA) Less Than $500K
- Potential Customers Excited by Low-Cost Launch Prospects

ESPA Customers

- "Road Show" Briefing Given to Potential ESPA Customers
- AFSPC/NASA/NRO Partnership Council
  - General Myers, Mr. Goldin, Mr. Hall
- SMC
  - EELV SPO/Boeing/Lockheed-Martin
  - Action-Officers at GPS, DMSP, DSCS
  - Presentations Planned for PMs
- HQ AFSPC DR/DOY/XPX

ESPA Customers (cont.)

- Naval Research Lab
- NASA
  - Goddard SFC
  - Jet Propulsion Laboratory
  - Assistant Administrators, KSC (scheduled)
- Industry/Academia
  - University Space Research Association
  - Ball Aerospace
  - AIAA Conferences (scheduled)

Conclusion

- Small Satellites are Useful, But US Lacks SmallSat Launch Infrastructure
  - Hard to fulfill STP mission
  - Potential impact to future AFSPC missions
- ESPA Carries Up to Six SmallSats and Offers "Soft Ride" to Primary and Secondary Payloads
- Launch Cost Per Satellite Drops from $7M-$10M to $320k to $850k

GSFC

NASA's Pucksat Payload Adapter

Presented At
EELV Secondary Payload Symposium

Aerospace Corporation
El Segundo, CA

March 31, 1999

Presentation Outline

- Pucksat Concept
- Pucksat Design and Payload Configurations
- Major Structural Interfaces
- User Accommodations
- Milestones
- Cost & Schedule
- Lessons Learned
- Points of Contact
- Conclusions

"Fabrication Drawings Exist for a Structure to Carry Small Payloads to Utilize L/V Excess Performance"

Pucksat Concept

Background

- Historically Delta II launches have had payload margins suitable for small satellites. For example, Landsat-7 has 1152 kg margin.
- Pucksat concept created to provide increased access to space by making efficient use of payload margins.
- Goal is to provide Delta II 2nd stage compatible standard structure capable of enabling variety of science missions with wide range of satellite configurations.
- Example missions and configurations are as follows:
  - Pucksat Dedicated Mission Configuration
    Entire spacecraft dedicated to a single experimenter.
  - Pucksat Instrument Carrier Configuration
    Spacecraft utilized by two or more experimenters.
  - Pucksat Multiple Payloads Carrier Configuration
    Spacecraft utilized to dispense multiple small payloads.
  - Multiple Pucksats Stacked Configuration
    Suitable for constellation mission.

Golden Directive

"Launch 12 Small Payloads per Year With an Increase Within 3 Years to 24 per Year"

Initially:

5 Code S Payloads

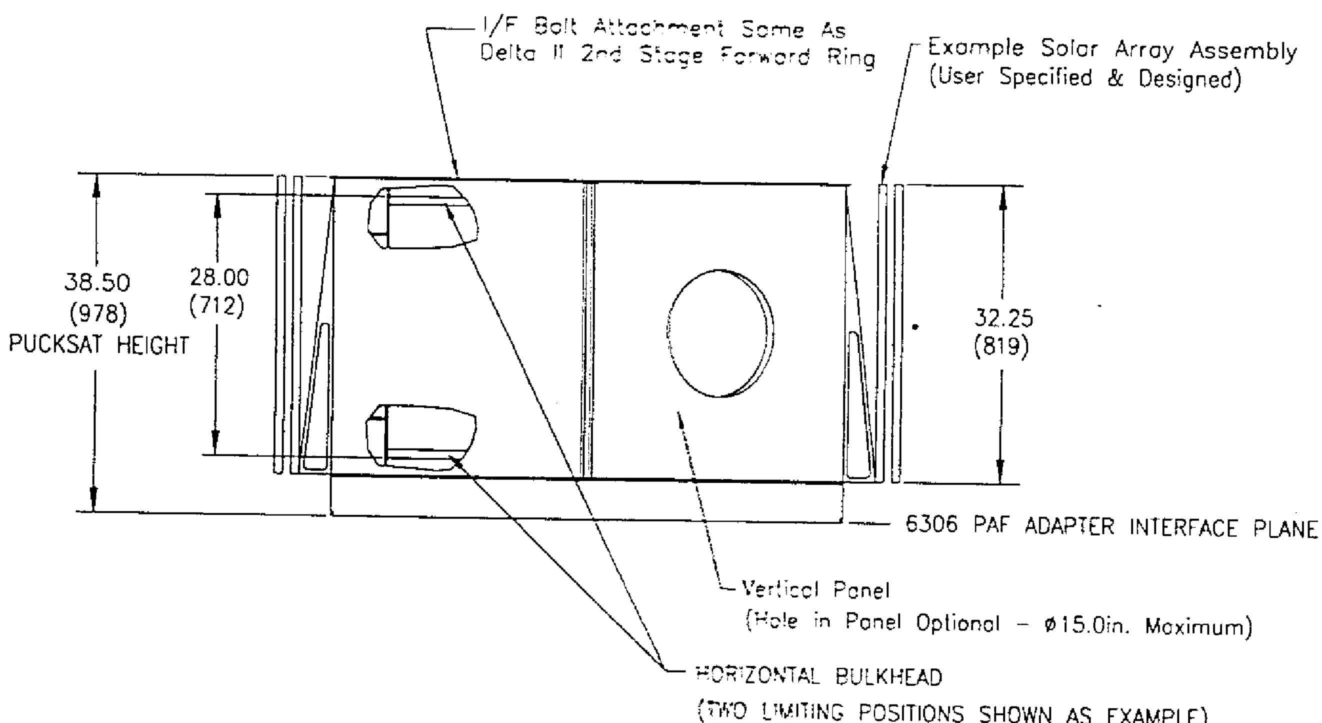
5 Code Y Payloads

2 Code U Payloads

Pucksat Design and P/L Configurations

Pucksat – Side View

1. DIMENSIONS SHOWN : INCHES (mm)

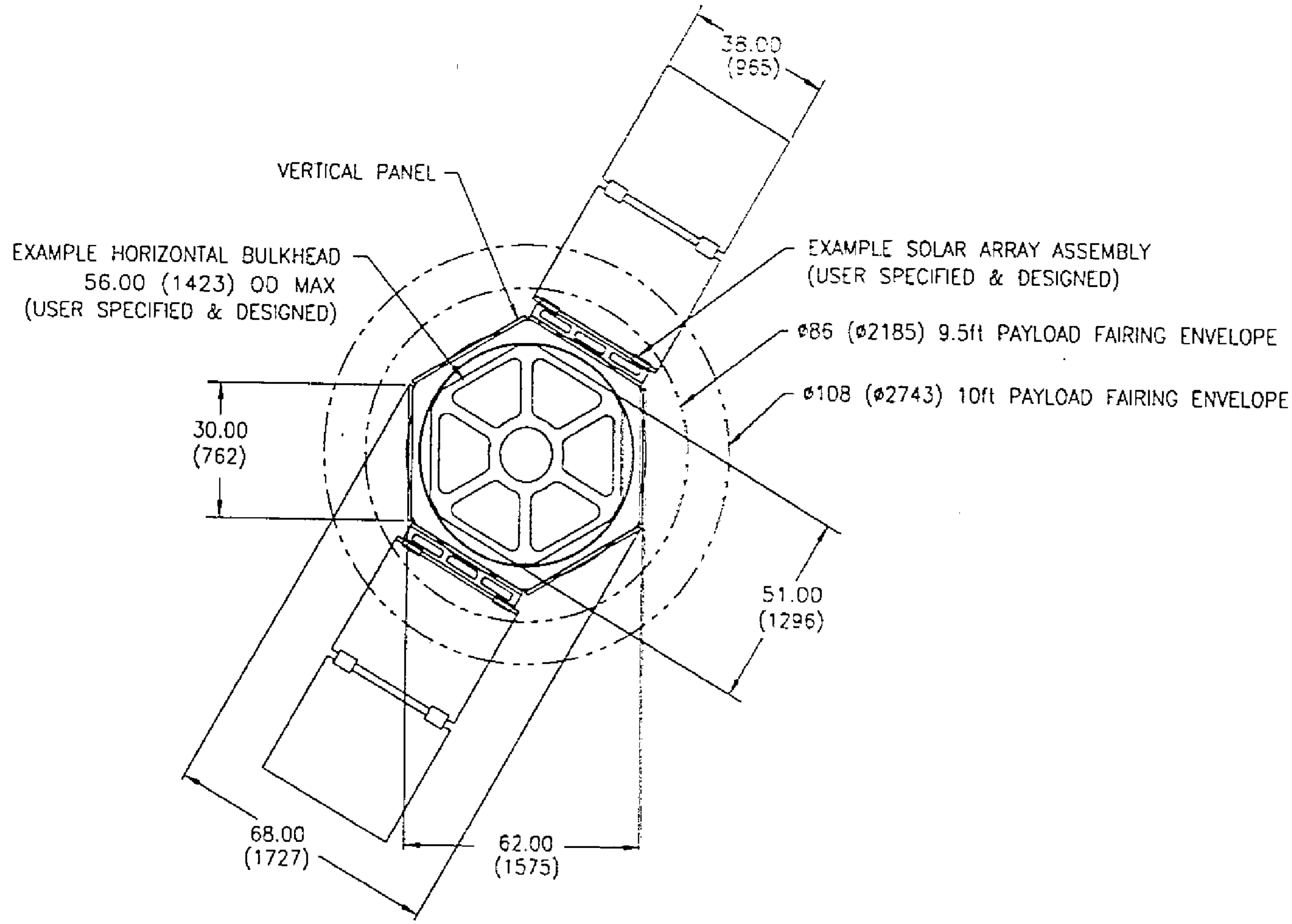


Notes: 1. Pucksat height is scaleable downward from 38.5in.(978mm) to customer established lower limit.

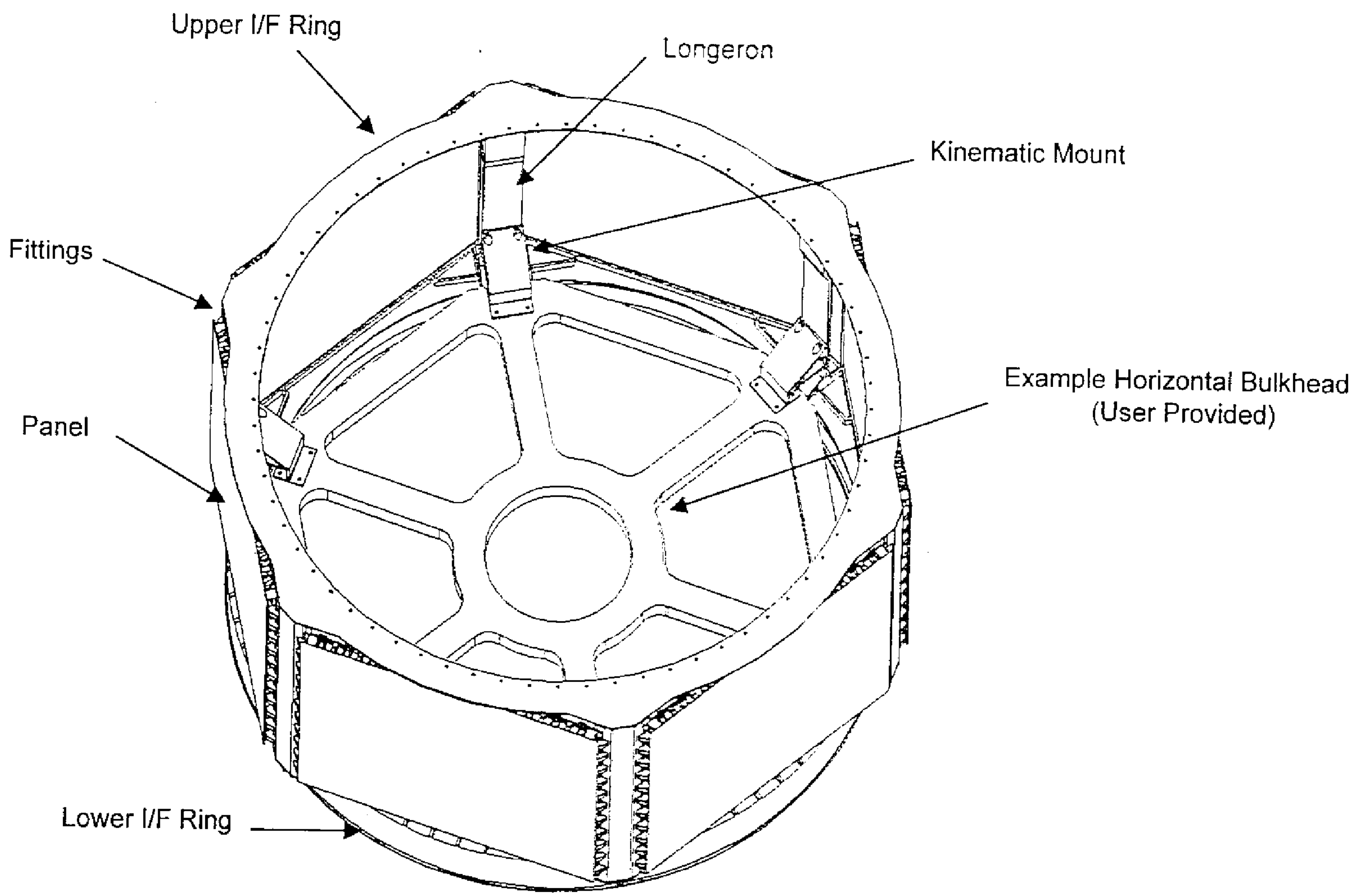
2. Size of shown vertical panels is 30in. X 30in. (762mm x 762mm)

Pucksat – Plan View

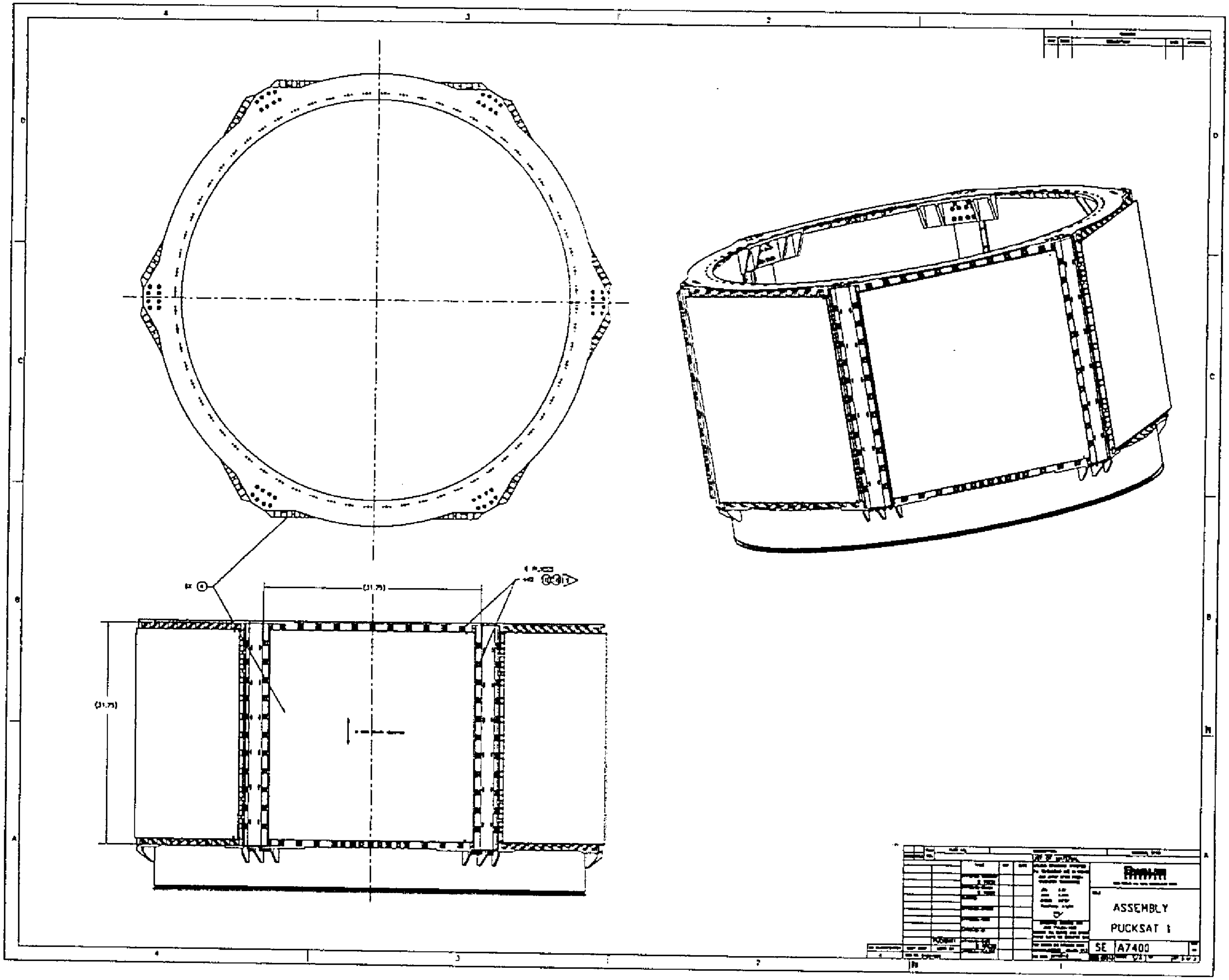
1. DIMENSIONS SHOWN : INCHES (mm)



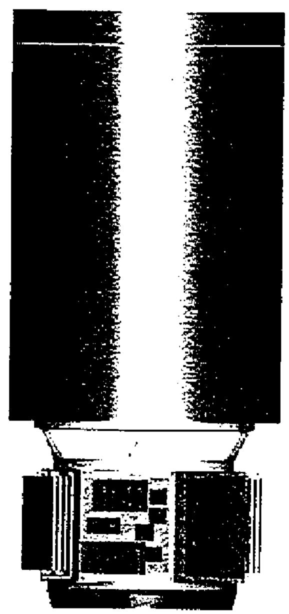
Pucksat – Basic Structural Elements



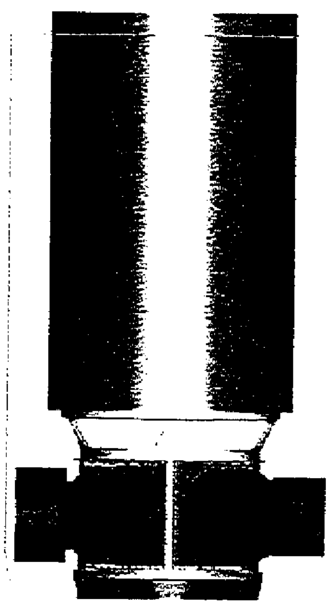
Pucksat Assembly Drawing



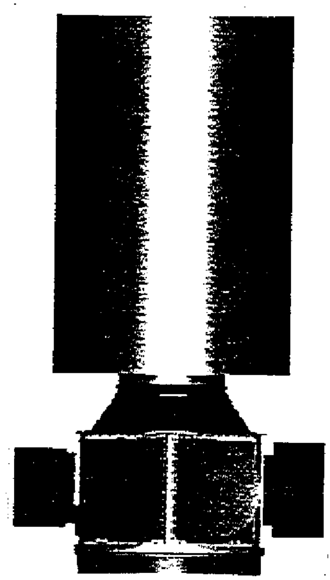
Example Pucksat Payload Configurations



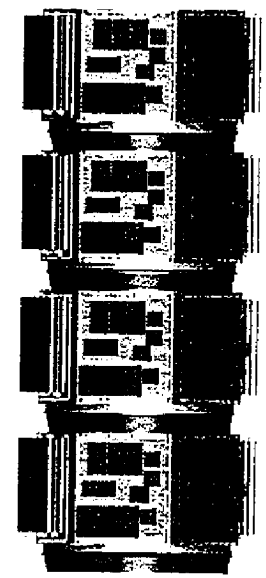
Pucksat as Dedicated Mission or Instrument Carrier



Pucksat as Multiple Payload Carrier



Pucksat as Hybrid Configuration



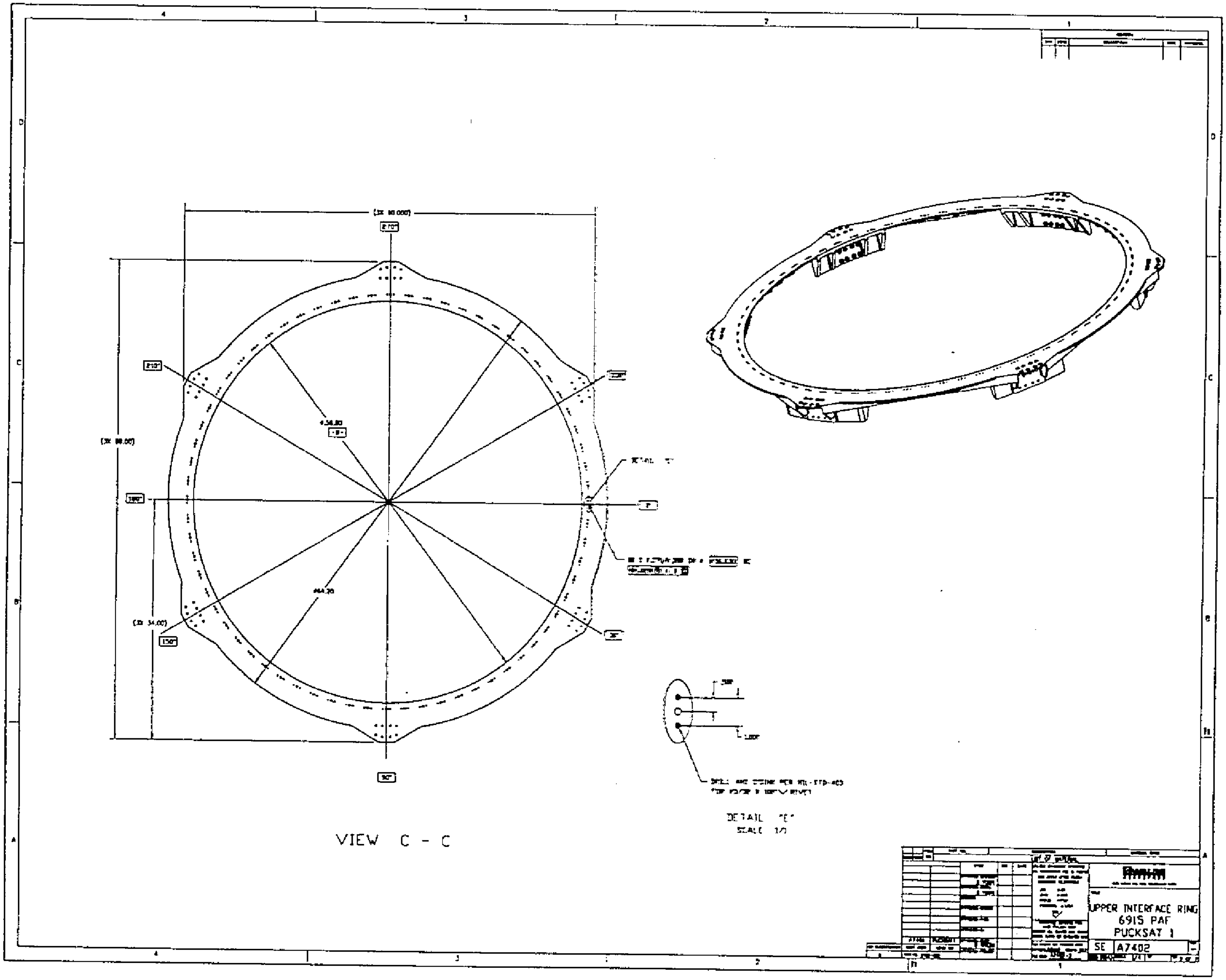
Pucksat as Stacked Constellation Mission

Major Structural Interfaces

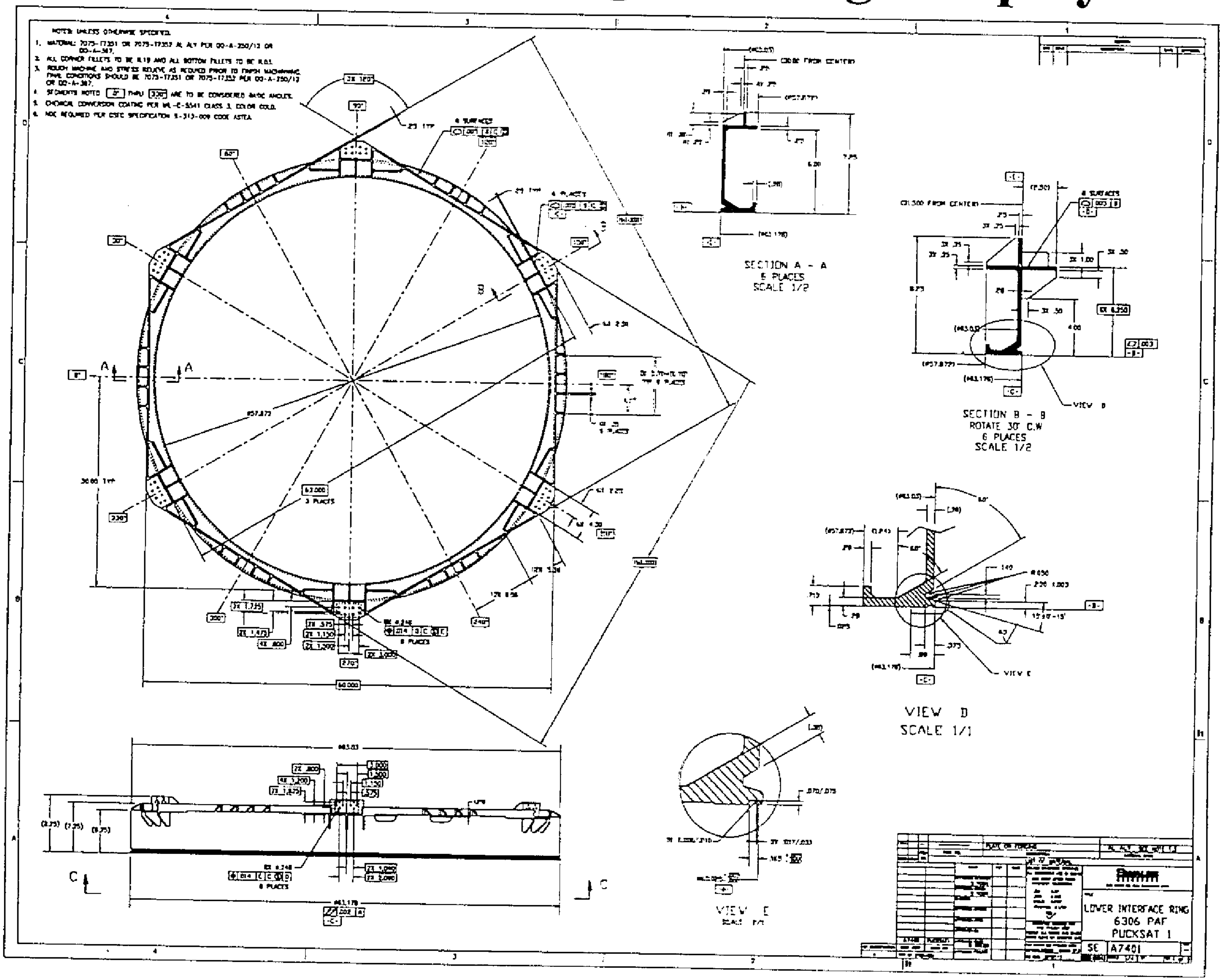
Pucksat Upper and Lower Interfaces

- Upper I/F Ring bolt attachment same as Delta II 2^{nd} stage Forward Ring 56.83" dia. circle (64 bolts).
- Simple stub adapter(s) can be provided to allow variety of different primary payload I/F attachments.
- Lower I/F Ring-Deployable mates to Delta 6306 PAF.
- Lower I/F Ring-Fixed bolt pattern also matches Delta II 2^{nd} stage Forward Ring.
- Optional Lower I/F Ring-Fixed design readily derived from existing design to match EELV standard 62.01" dia. bolt circle (121 bolts).
- See next six charts.

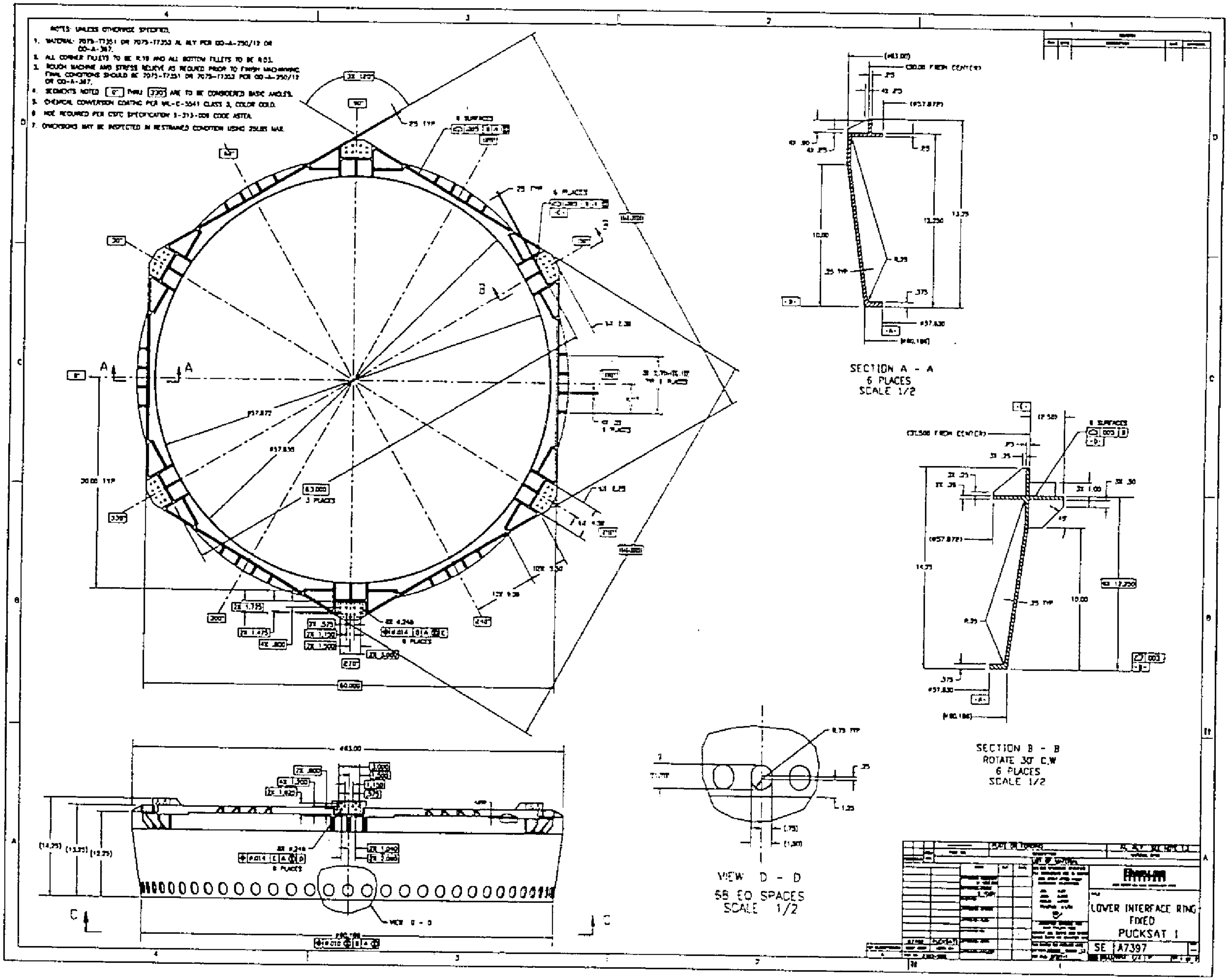
Pucksat Upper I/F Ring Drawing



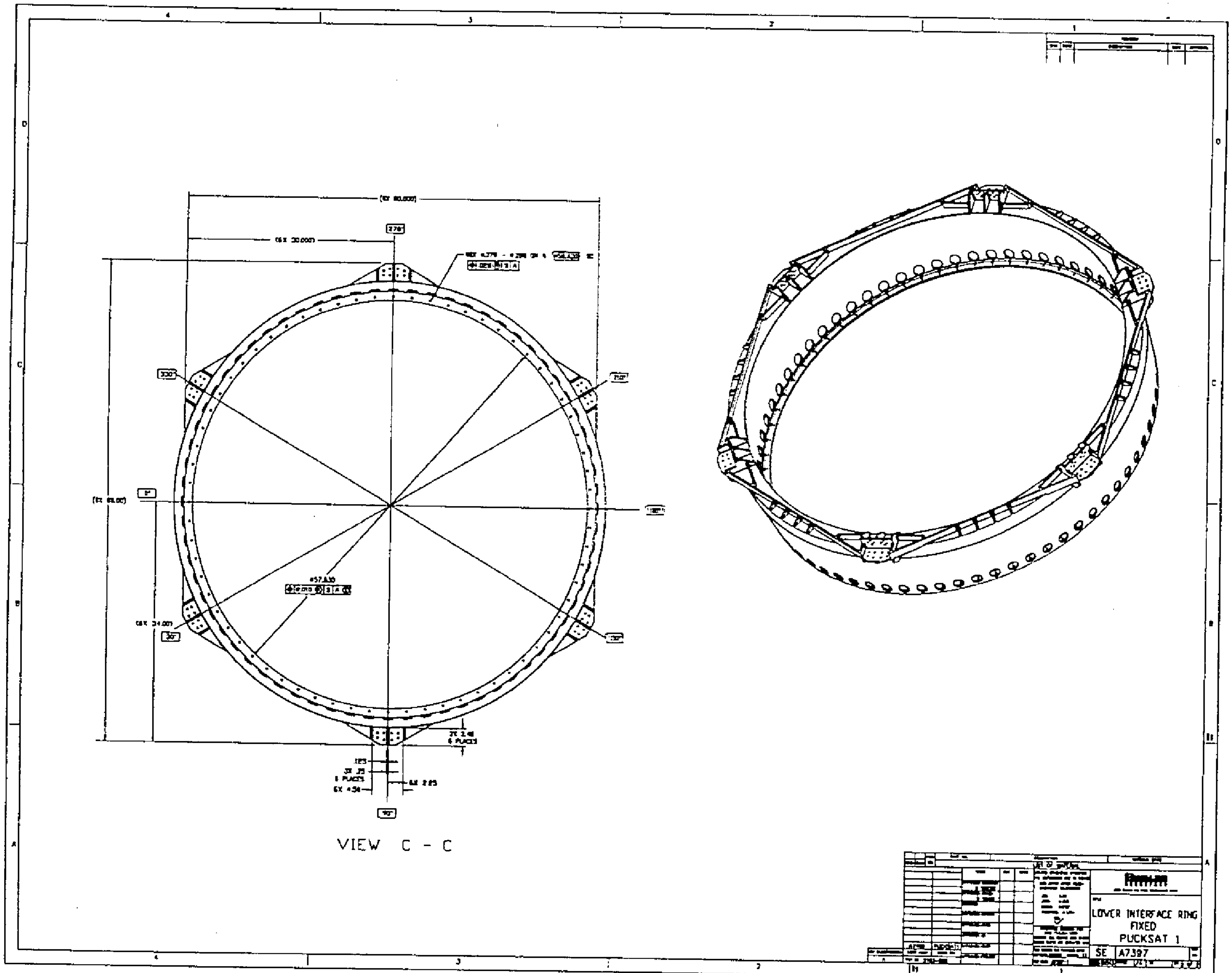
Pucksat Lower I/F Ring Drawing - Deployable



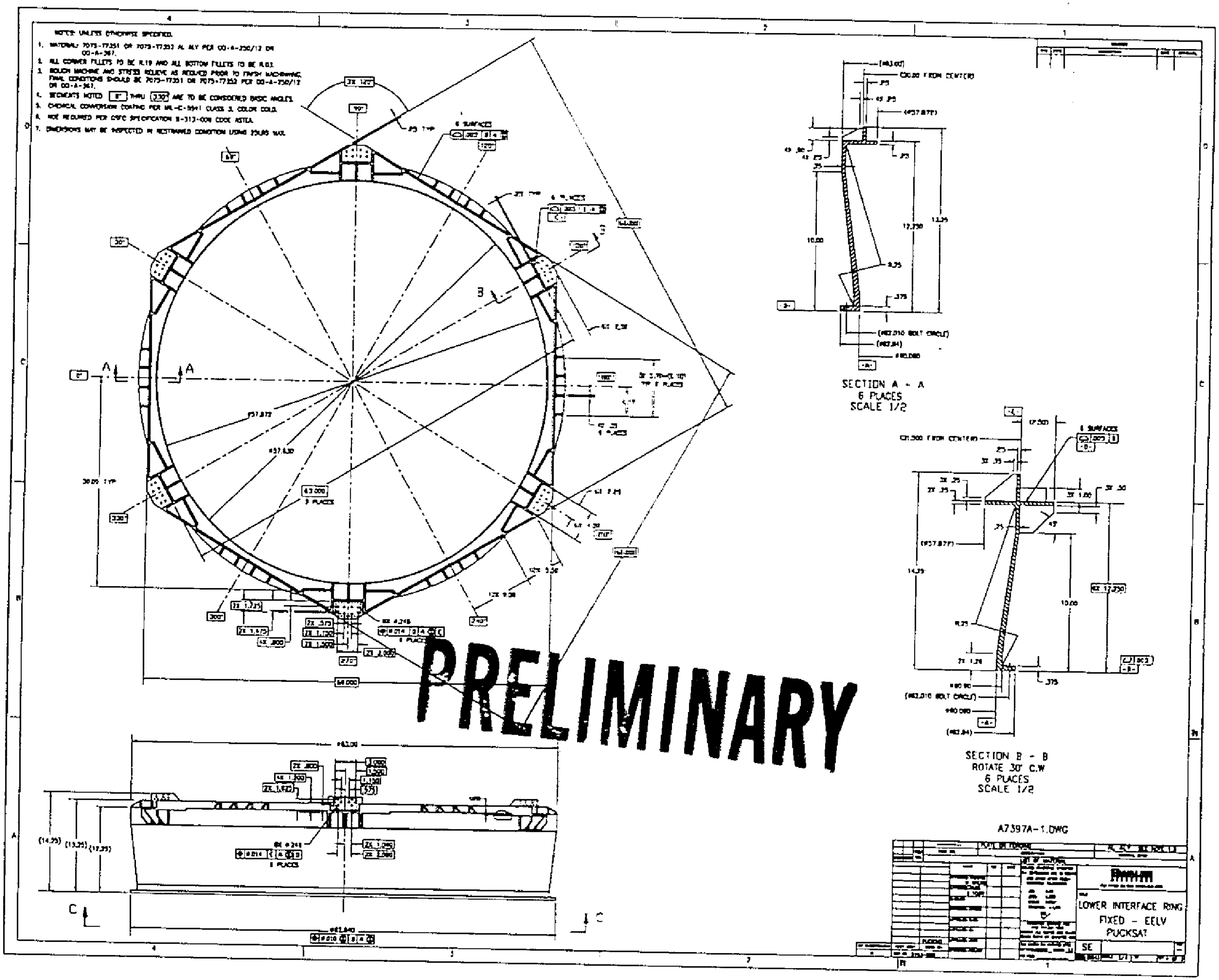
Pucksat Lower I/F Ring Drawing– Fixed



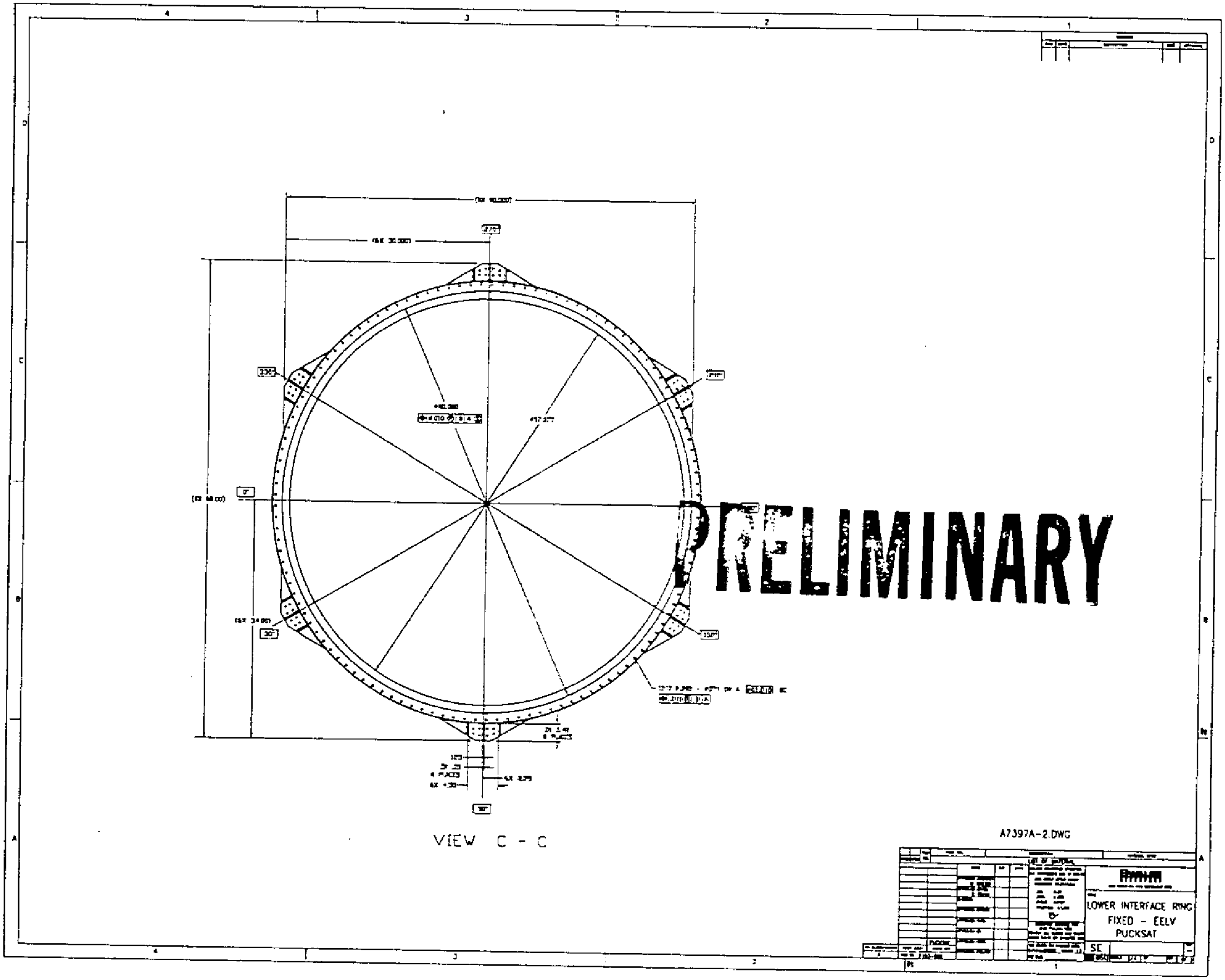
Pucksat Lower I/F Ring Drawing – Fixed



Pucksat Lower I/F Ring Drawing – Fixed (EELV)



Pucksat Lower I/F Ring Drawing – Fixed (EELV)



User Accommodations

Pucksat Payload Capacity

- Empty Mass = 125 kg (275 lbm)
- Maximum Primary Payload = 5000 lbm with cg 60" above I/F
- Vertical Panels

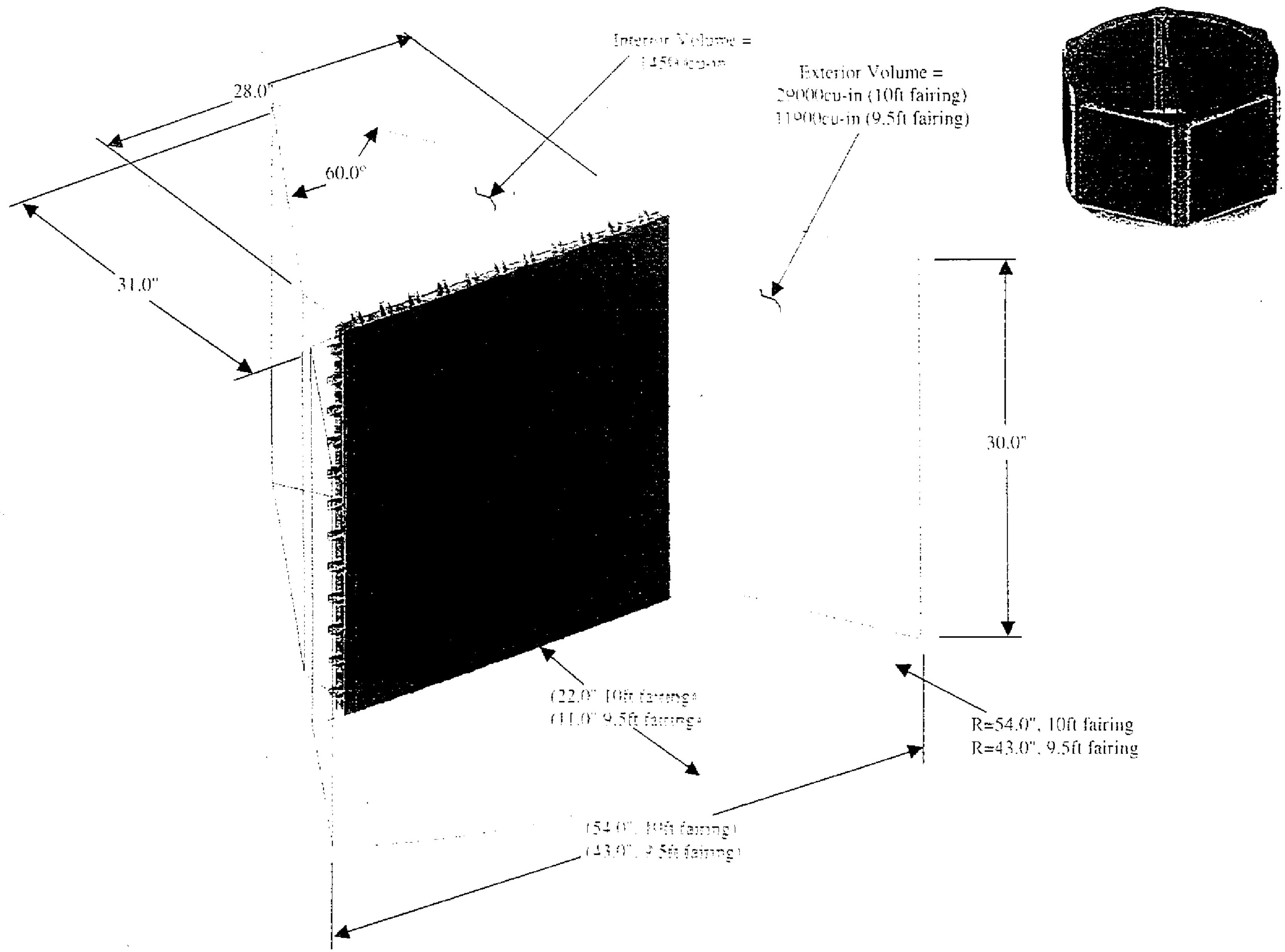
  113 kg (250 lbm) maximum payload per panel

  Payload not to exceed 351 kg (775 lbm) for all six panels combined

  Exterior payload maximum size - 20" x 28" x 30" prism per panel
- Horizontal Bulkhead

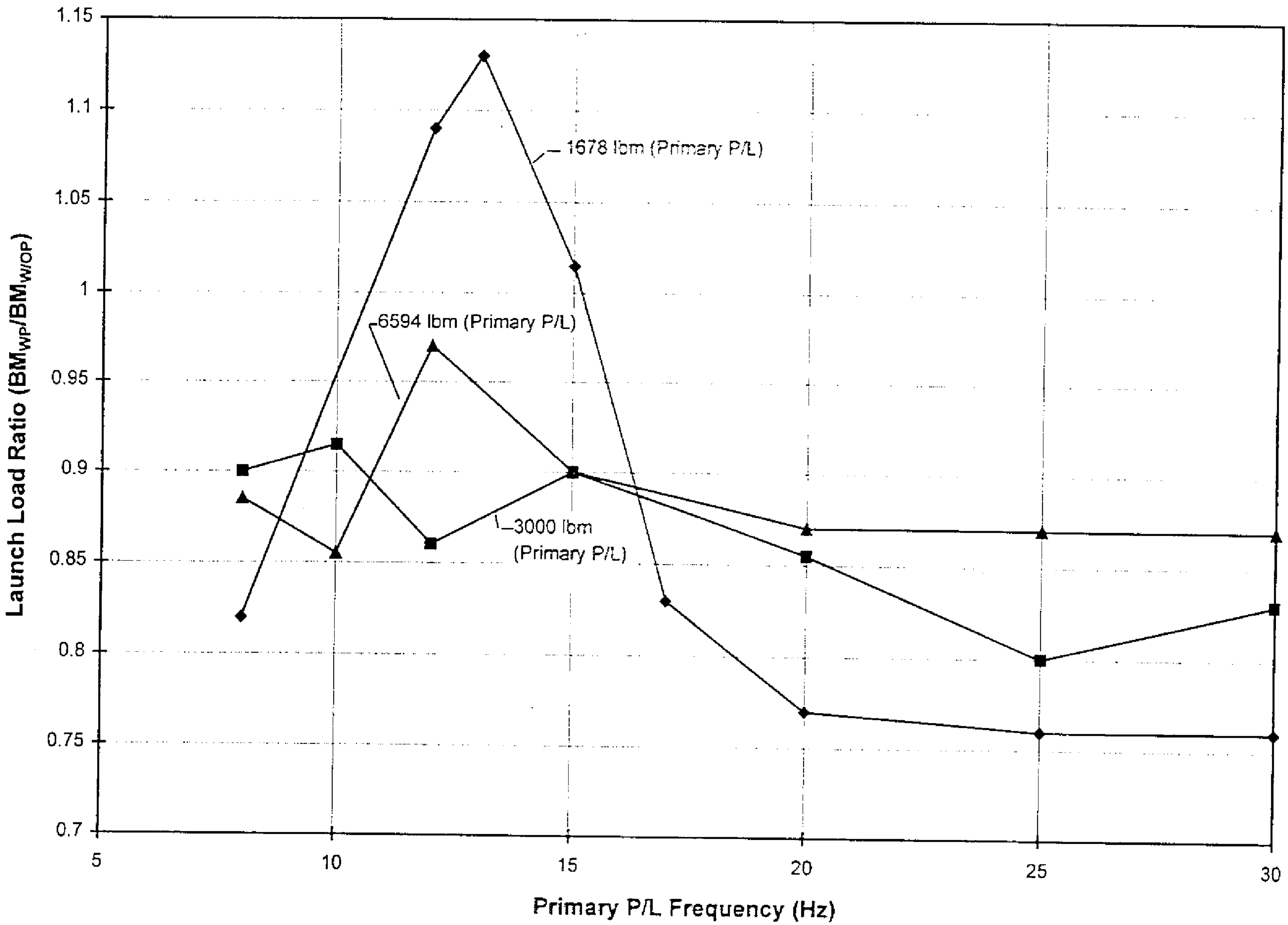
  227 kg (500 lbm) maximum payload

  Payload maximum size - 56 in. dia. x 30 in. height cylindrical prism
- Grand Total Maximum Payload Capacity = 578 kg (1275 lbm)



Usable Pucksat Envelope (per panel) - 38.5" Pucksat

Pucksat - Effect On Primary Payload Delta Launch Loads

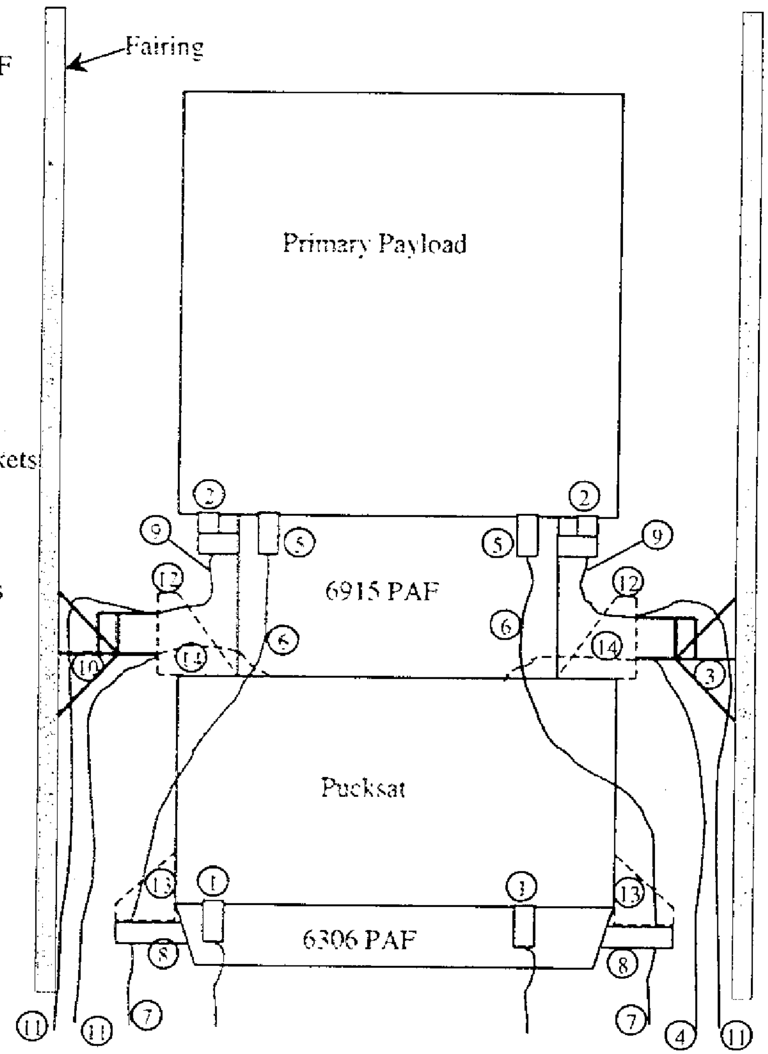


Pucksat – Example Harness Requirements

Standard Parts (Green):
1. Pyros and harness for 6306 PAF
2. Brackets to primary P/L
3. One fairing bracket
4. One harness to fairing bracket

Additional Parts (Red):
5. Pyros to primary P/L
6. Upper pyro extension harness
7. Delta II pyro harness
8. Upper pyro extension brackets
9. Primary P/L to Delta harness
10. One fairing bracket
11. Three harnesses to fairing brackets

Pucksat Parts (Blue):
12. Upper harness pull-off brackets
13. Lower harness pull-off brackets
14. Pucksat wire harness



Milestones

Major Milestones

• Concept Study Presentation	02/06/97
• Customer Surveys Completed	08/06/97
• PDR	07/16/98
• CDR	10/01/98
• Fabrication Drawings Delivered	11/20/98

Cost & Schedule

Pucksat Cost

Pucksat Budget (99$)*

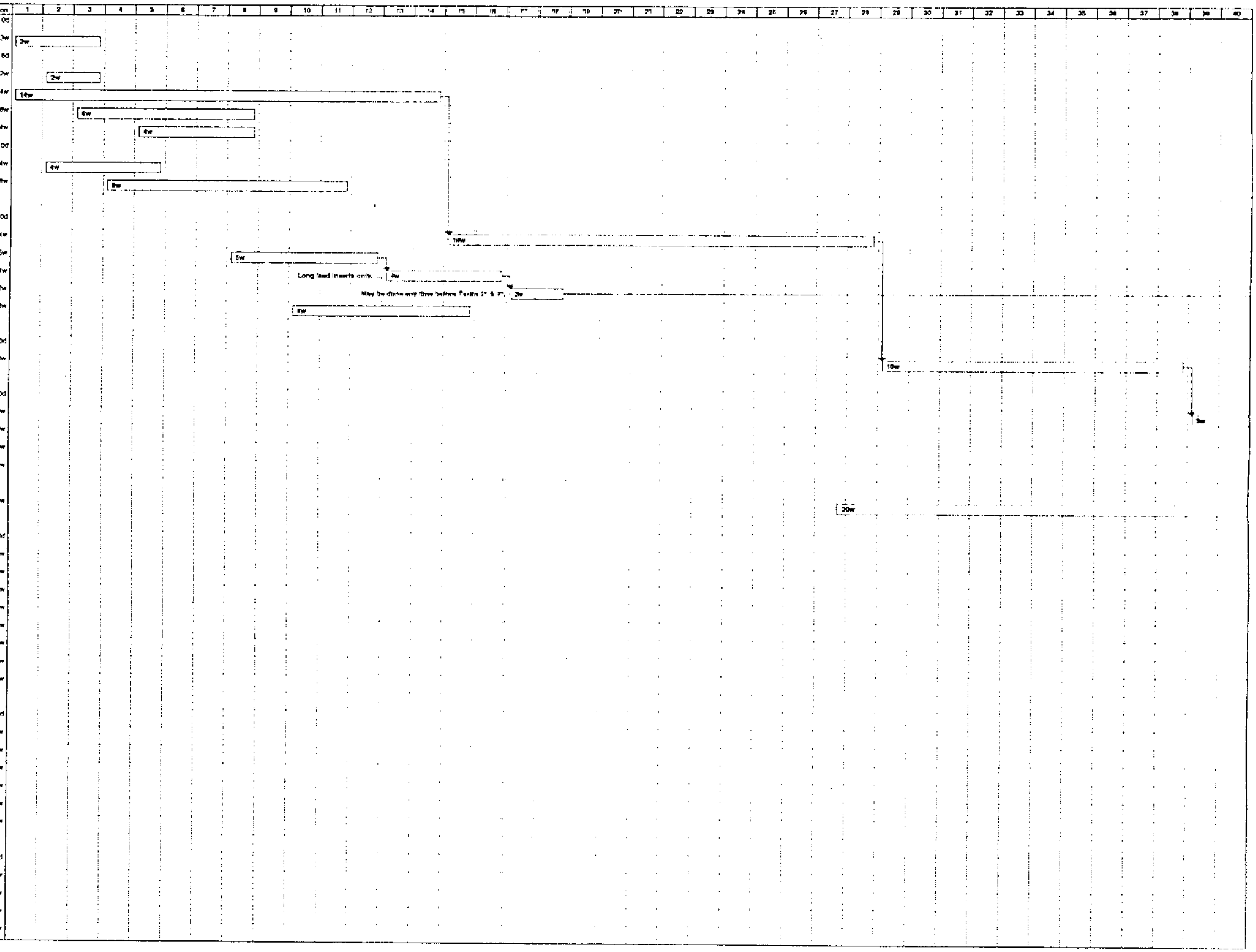
Pucksat Fabrication & Qualification Test Cost			Estimated Pucksat Spacecraft Flight Cost		
Category	First Unit	Recurring	Category	First Mission	Recurring Mission
Fabrication & Assembly	$470K	$270K	Boeing Integration	$4,576K	$4,576K
Qualification Test	$130K	$130K	Launch Site Support Launch Site Integration Facility	$300K (Shared)	$300K (Shared)
24 in. PAF Procurement	$78K	$78K Each **			
17 in. PAF Procurement	$90K	$40K Each	Payload Attach Fittings (Assume 5 Added PAF's)	$200K	$200K
Subtotal	$768K	$518K			
GSFC Manpower	$62K	$31K	Pucksat Structure	$830K	$549
Total	$830K	$549K	GSFC Manpower	$134K	$134
			Travel	$54K	$54
			Grand Total (No Travel)	$6,040K (7 P/L's) $863K Each P/L	$5,759K (7 P/L's) $822K Each P/L

* 01/22/99 GSFC Full Cost Format

** 30% Discount For Purchase of 4 or More

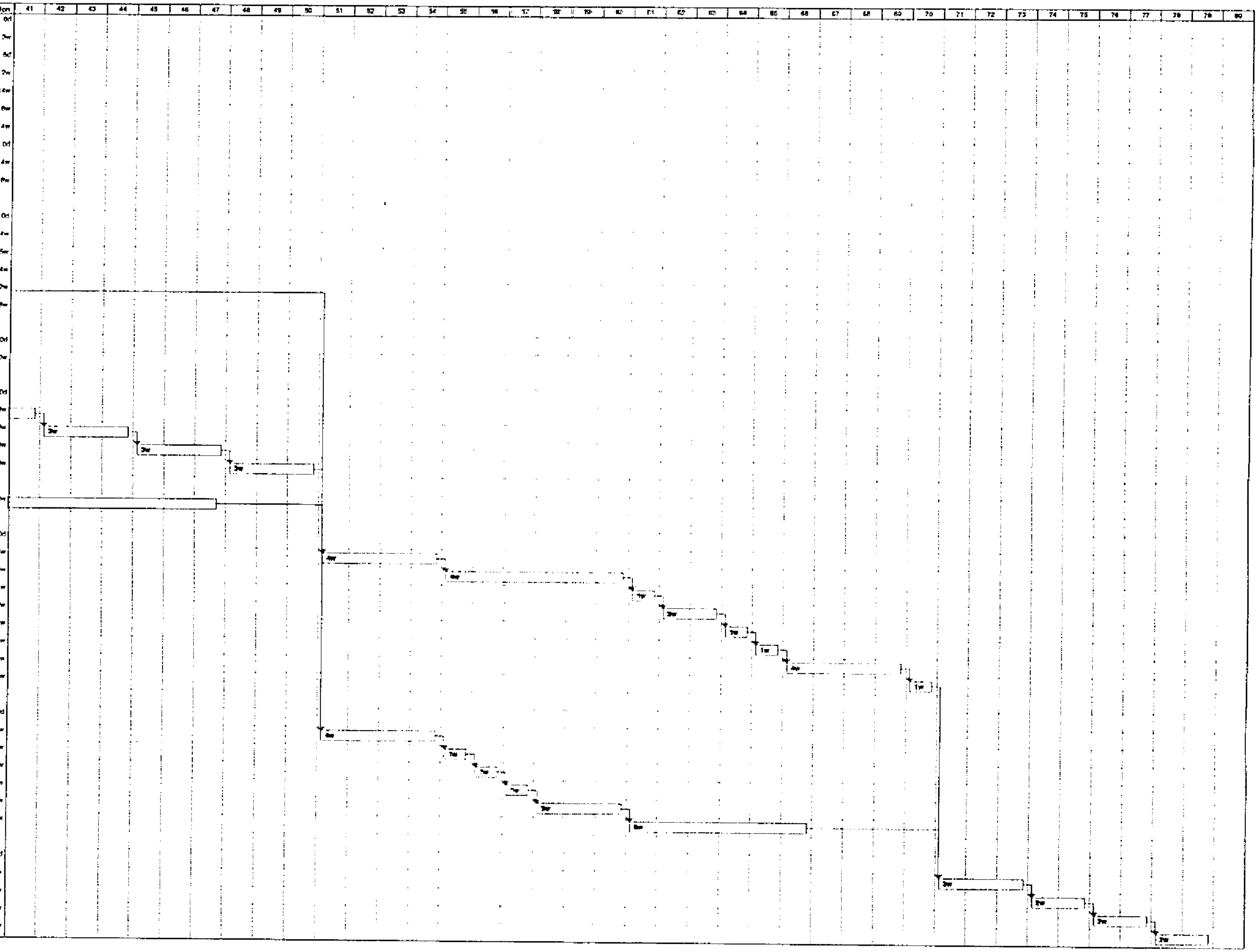
Pucksat ATP to Flight Schedule

ID	Task Name	Duration
1	Planning (Mfg. Engr.)	0d
2	Bill of Materials	3w
3	Long Lead Items	0d
4	Planning	2w
5	Forgings	14w
6	Adhesive	8w
7	Hardware	4w
8	Tooling	0d
9	Design	4w
10	Fabricate & Inspect	8w
11		
12	Fabrication	0d
13	Rings Machined	14w
14	Panels Bonded	5w
15	Panel Insert Installation	4w
16	Component Fit Checks	2w
17	Machine Details	6w
18		
19	Assembly	0d
20	Pucksat Structure	10w
21		
22	Testing	0d
23	Mass Properties	2w
24	Modal Survey	2w
25	Static	3w
26	Closing Paperwork	2w
27		
28	Clampband Procurement	20w
29		
30	Dedicated P/L Integration	0d
31	Panel Prep (inserts, holes, etc.)	4w
32	Mount Components	6w
33	Panel Modal Test	1w
34	Panel Thermal Test	2w
35	Panel Vibration Test	1w
36	Panel Acoustic Test	1w
37	Panel Electrical Test	4w
38	Panel to Pucksat Integration	1w
39		
40	Multiple P/L Integration	0d
41	Panel Prep (inserts, holes, etc.)	4w
42	Mount PAF	1w
43	P/L & Clampband Installation	1w
44	Panel to Pucksat Integration	1w
45	Harness Installation	2w
46	Testing	6w
47		
48	Delivery	0d
49	Final Inspection	2w
50	Packaging	2w
51	Transportation	2w
52	Launch Site Preparation	2w



Pucksat ATP to Flight Schedule

ID	Task Name	Duration
1	Planning (Mfg. Engr.)	0d
2	Bill of Materials	3w
3	Long Lead Items	0d
4	Planning	2w
5	Forgings	14w
6	Adhesive	6w
7	Hardware	4w
8	Tooling	0d
9	Design	4w
10	Fabricate & Inspect	6w
11		
12	Fabrication	0d
13	Rings Machined	14w
14	Panels Bonded	5w
15	Panel Insert Installation	4w
16	Component Fit Checks	2w
17	Machine Details	6w
18		
19	Assembly	0d
20	Pucksat Structure	10w
21		
22	Testing	0d
23	Mass Properties	3w
24	Modal Survey	3w
25	Static	3w
26	Closing Paperwork	3w
27		
28	Clampband Procurement	20w
29		
30	Dedicated P/L Integration	0d
31	Panel Prep (Inserts, holes, etc.)	4w
32	Mount Components	6w
33	Panel Modal Test	1w
34	Panel Thermal Test	2w
35	Panel Vibration Test	1w
36	Panel Acoustic Test	1w
37	Panel Electrical Test	4w
38	Panel to Pucksat Integration	1w
39		
40	Multiple P/L Integration	0d
41	Panel Prep (Inserts, holes, etc.)	4w
42	Mount PAF	1w
43	P/L & Clampband Installation	1w
44	Panel to Pucksat Integration	1w
45	Harness Installation	3w
46	Testing	6w
47		
48	Delivery	0d
49	Final Inspection	3w
50	Packaging	2w
51	Transportation	2w
52	Launch Site Preparation	2w



Lessons Learned

Lessons Learned

- Possibly no significant change in primary P/L structure loads.
- Avoid transmitting overly concentrated loads to L/V interface.
- Make early accommodation for wiring & ordnance from L/V.
- Make six side panels fully interchangeable.
- Make primary structure height scaleable.
- Design for maximum possible size primary P/L.
- Make maximum use of inside & outside usable volumes.
- Provide both deployable and non-deployable configurations.

Lessons Learned

(cont'd)

- Create IPT to thoroughly understand users needs ASAP.
- Start early to mitigate customer concerns & develop users .
- Give users options that can be readily incorporated.
- Give users large degree of P/L configuration flexibility.
- Build flight mass simulators for all P/L's to mitigate launch schedule risk.

Points of Contact

Pucksat Points of Contact

- Programmatic

NASA/Goddard Space Flight Center
Bruce Milam
Code 470
Greenbelt, MD 20771
Phone: 301-286-0429
e-mail: bruce.milam@gsfc.nasa.gov

- Technical

Swales Aerospace
Joseph Young
5050 Powder Mill Road
Beltsville, MD 20705
Phone: 301-902-4162
e-mail: pyoung@swales.com

Swales Aerospace
Matt Krebs
5050 Powder Mill Road
Beltsville, MD 20705
Phone: 301-902-4539
e-mail: mkrebs@swales.com

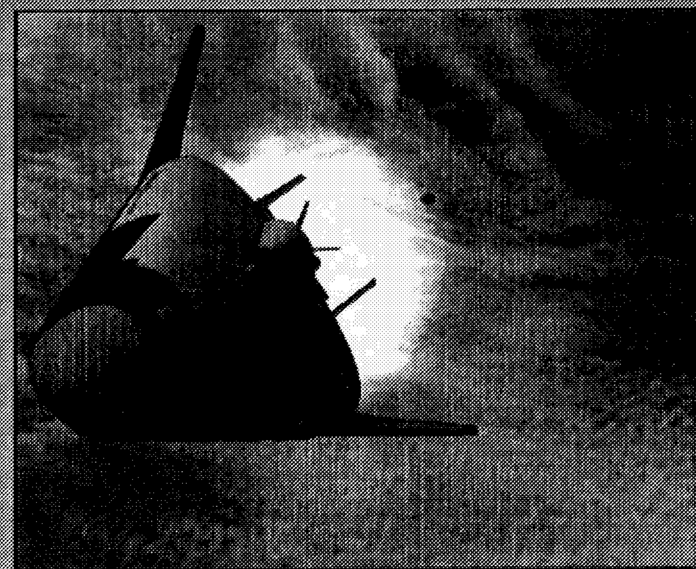
Conclusions

In Conclusion

- Pucksat is a low cost, mass efficient way to avoid performance waste on the Delta II.
- Pucksat fabrication drawings are completed and ready for production.
- Upper I/F stub adapter(s) can be provided to accommodate variety of primary payload attachments.
- Pucksat Lower I/F Ring readily modified to match EELV standard interface.
- Pucksat can be flown for a total recurring cost of approximately $5.7 M and be ready for payload installation 50 weeks ATP and ready for Delta II integration approximately 79 weeks ATP.

"Currently looking for a flight opportunity"

Military Spaceplane Overview for NRO Shareride Conference

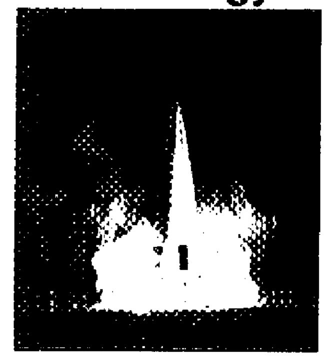


Lt Col Ken Verderame
Air Force Research Laboratory
16 April 1999

What Is a Military Spaceplane?

- Reusable System
  - Timely and Routine Delivery of Mission Assets To, Through and From Space
  - Multi-Mission Capable With Interchangeable Payloads
  - Rapid Turn Time

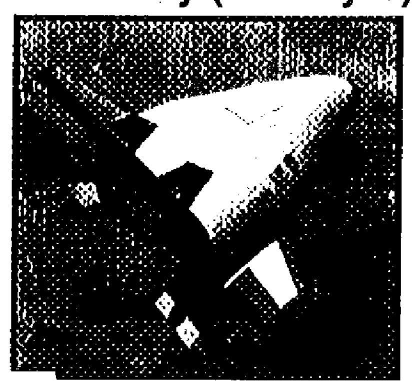
Technology



Ops Demonstrator
Availability (5-10 yrs)

- Space Control
  - Recce, protection
- Force Enhancement
  - Recce
- Space Support
  - Spacelift <4Klbs

Orbit Capable MSP
Availability (10-20 yrs)



- Much Greater Payload
- More Capability
- Extended On-Orbit Maneuvering

Military Spaceplane (MSP) System Architecture

Reusable First Stage

NASA - Lead
- NASA Cooperative Technologies based on Performance needs
- AF Concentrate on Ops Technologies

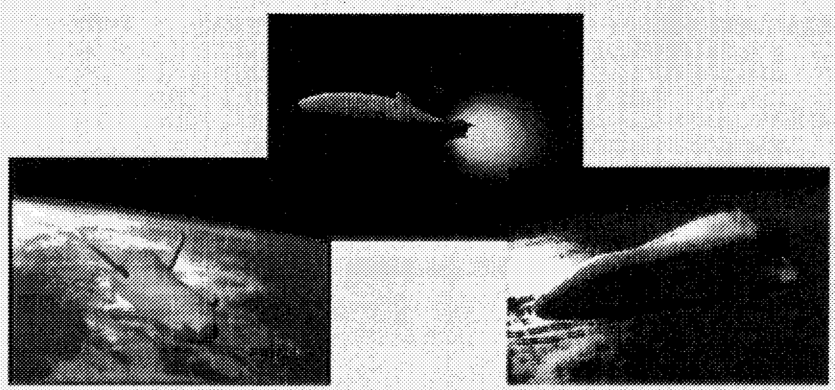

Military Spaceplane (MSP)

All S&T Technology Supports TSTO MSP

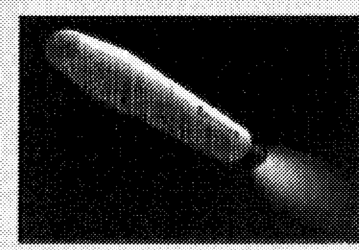
Payloads Second Stage

AF - Lead

Integrated Technology Needed

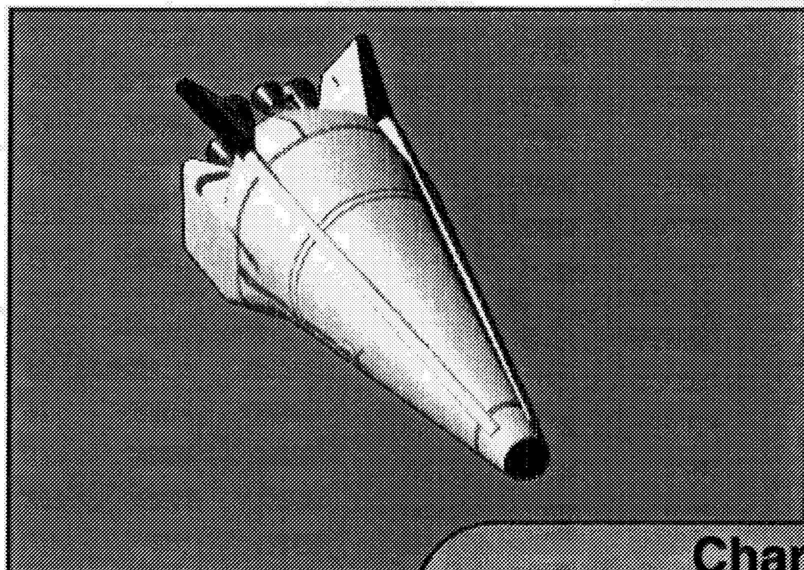


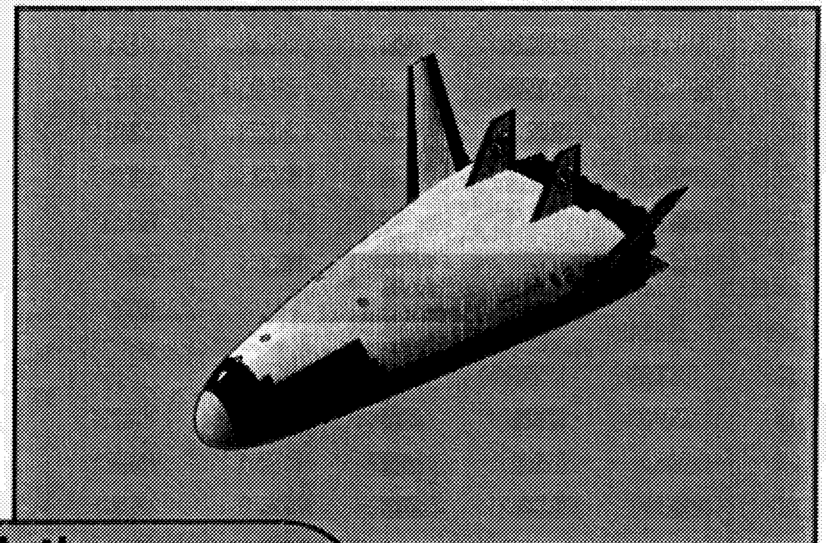
Space Maneuver Vehicle (SMV)
Reusable Satellite Bus/Upper Stage



Modular Insertion Stage (MIS)
Low Cost Expendable Upper Stage

TSTO Military Spaceplane





Characteristics

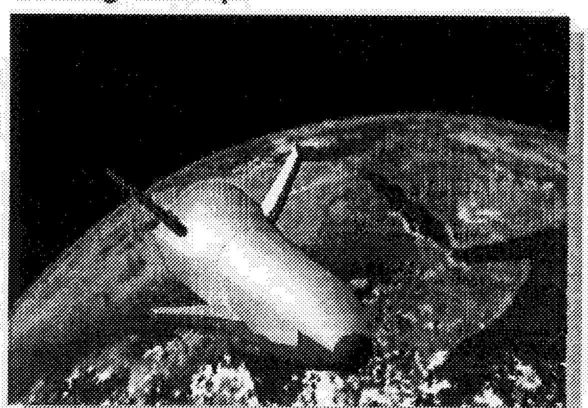
Length	~60ft
Glow	~300-600Klbs
Dry Weight	~40-80Klbs
	(configuration dependent)
Payload	12Klbs
Max Speed	Mach 15-18
Orbit Access	Suborbital

Space Maneuver Vehicle
(Fully Reusable Satellite Bus/Upper Stage)

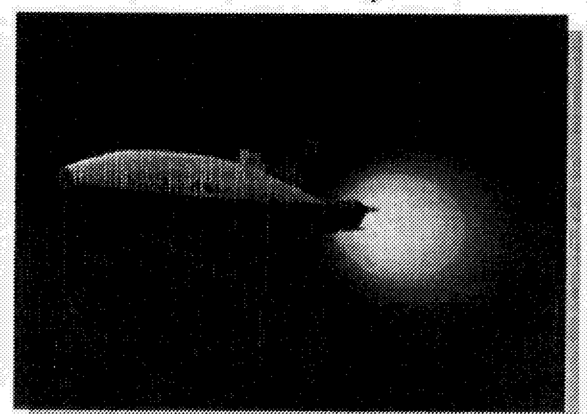
Characteristics

Length	20-25ft
Loaded Weight	11-12,000lbs
Dry Weight	25-3000lbs
Payload	1200lbs
Payload Bay	4ft x 7ft
ΔV Ideal	10,500-12,000fps

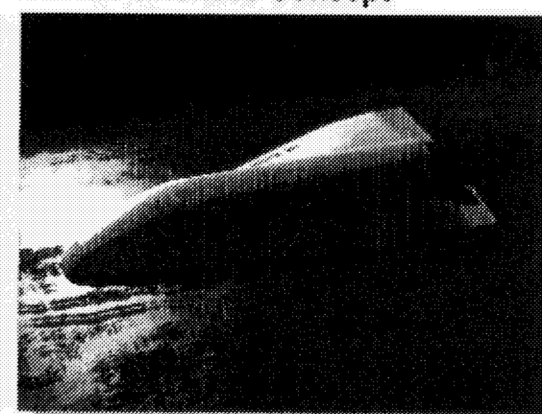
Boeing Concept



Lockheed-Martin Concept



Orbital Sciences Concept



Space Maneuver Vehicle
(Fully Reusable Satellite Bus/Upper Stage)

Characteristics

Length	20-25ft
Loaded Weight	10-12,000lbs
Dry Weight	25-3000lbs
Payload	1200lbs
Payload Bay	4ft x 7ft
ΔV Ideal	10-12000fps

Missions

Sensor/Payload Test
Reconnaissance
Surveillance/Inspection
Space Object ID
Electronic Warfare

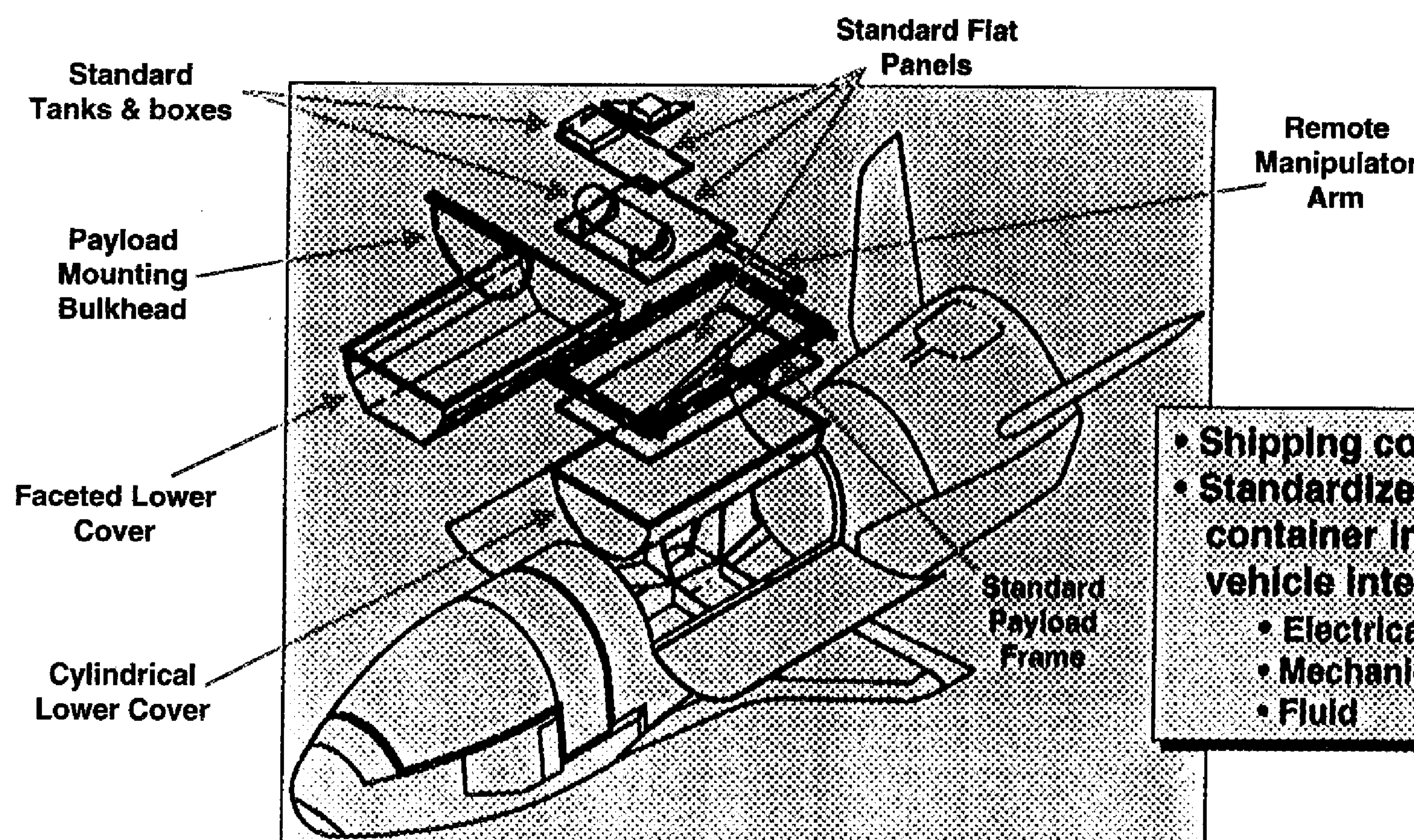
Employment

Pop-Up
LEO Co-orbit Capability
Fly-By of Higher Altitude Satellites
Constellation Building
Gap Filler

Features

On Demand Launch
Recallable/Recoverable
Short Notice Tasking
Landing Gear for Runway Recovery
Up to 12 Months on Orbit

Standardized Payload Container Offers Many Configuration Options to Users

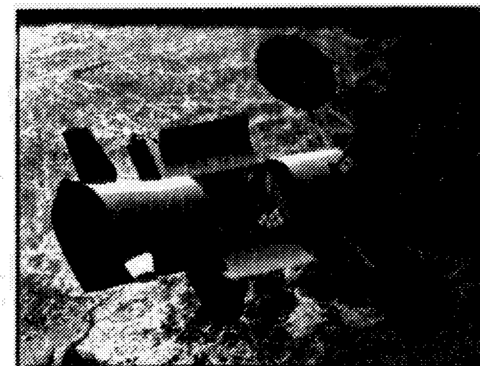


- Shipping container
- Standardized payload container incorporating vehicle interfaces
  - Electrical
  - Mechanical
  - Fluid

- Contamination control during transit and storage
- Reduced integration and checkout time
- Reduced turn time for payload swapout

AF/NASA "X-40B" Program

- **NASA Research Announcement 8-22**
  - ~$100M for Pathfinder and experiments
  - $20M congressional add for AF related activities
- **AF Participated in Source Selection**
- **Boeing Advanced Technology Vehicle (ATV) Chosen**
  - Very similar to AF Space Maneuver Vehicle (SMV)
  - Cooperative program between NASA and Boeing
- **AF is Providing $16.1M S&T Funds to Make ATV More Like SMV**
  - Solar array and power system for longer on-orbit time
  - Sensors and algorithms for rendezvous / proximity ops
  - Improved attitude / pointing system
  - Improved reentry maneuvering potential



	ATV	SMV
Dry Weight	4200 lbs *	3300 lbs
Payload	600 lbs *	1200 lbs
Velocity Change	7,200 ft/sec *	10,500 ft/sec
On-Orbit Duration	<12 hr *	12-15 mo
Design	modular	integrated
Engine	low performance	high performance

* Will Improve With AF Investment

98/99 Congressional Add Spend Plan

$5.0M Future-X ATV
$2.5M Propulsion for SMV/Upper Stage
$2.5M B-52 Releases of X-40A SMV

AF S&T Investment in Future-X /ATV

99	00	01	02
$5.0M	$5.0M	$5.1M	$1M

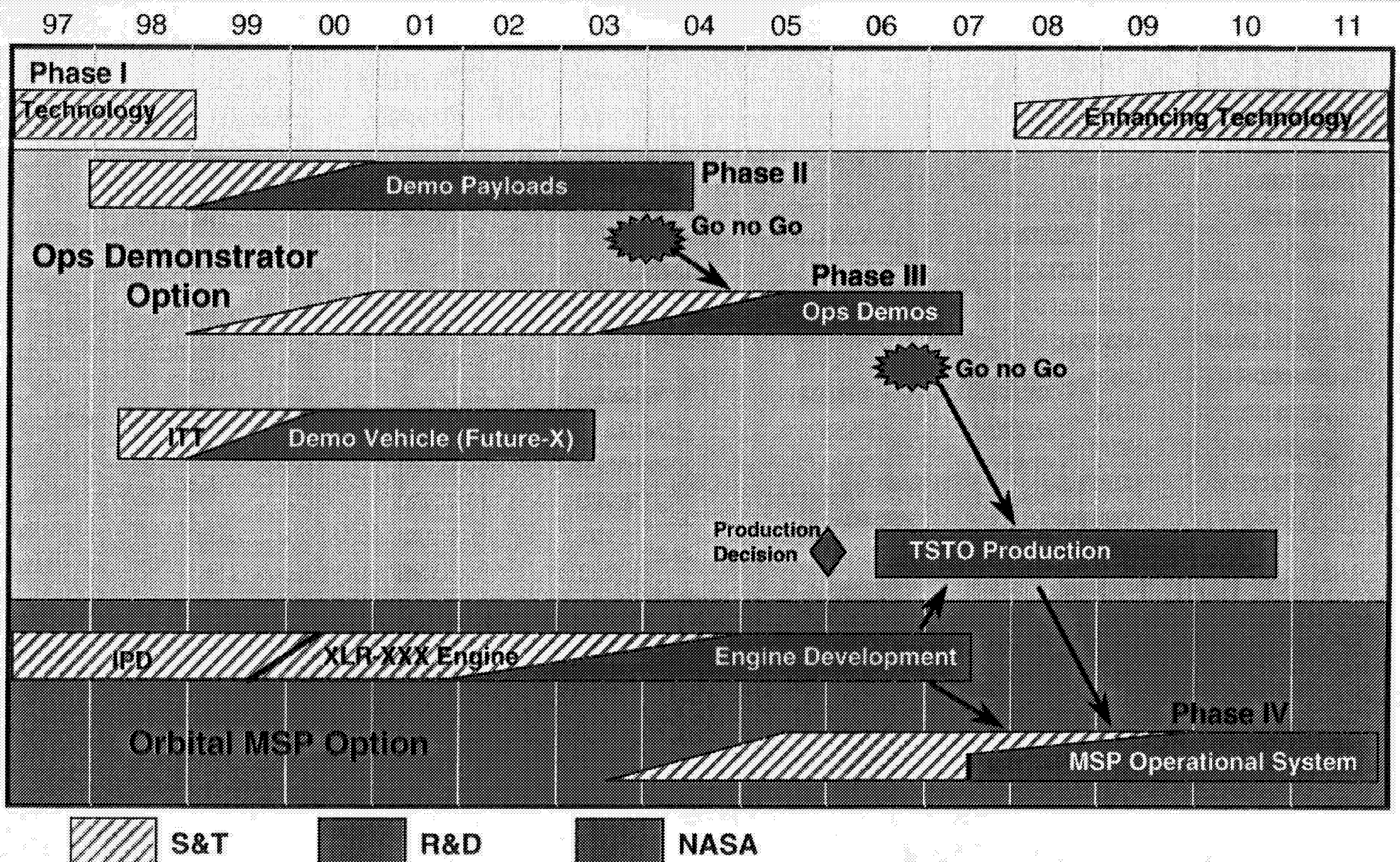
X-40B NBL Project

- Project Go-Ahead from Mr. Abbey Jun '98
- Funding Secured, project Kick-off Oct '99
- Objectives
  - Understand issues affecting vehicle design for planned shuttle mission
  - X-40B CDR: Jul '99
  - Need to incorporate into vehicle design prior to CDR
- Notional Shuttle Mission Outline
  - Conduct AF and NASA missions with X-40B during shuttle mission
  - Perform payload swap-out of X-40A via EVA
  - Perform re-fuel demonstration in between AF and NASA missions

X-40B NBL Project (cont.)

- **NBL Project to Look at Shuttle Integration / Crew Ops Issues Associated With This Type of Mission**
- **Specific NBL Objectives**
  - Conduct payload swap-out of 1000-1200 lb 4'x4'x'7 containerized payloads
  - Conduct refueling demonstration
  - No contingency EVA objectives
- **Schedule to be in the Water 10-12 May '99**
  - Day 1: Install mockup in pool
Scuba runs to check scenarios
  - Day 2: Run 1 MOD EVA/CB suited run to verify scenarios
Run 2 CB Ops run/eval
  - Day 3: Run 2 CB Ops run/eval
Run 2 CB Ops run/eval

MSP Technology/System Notional Development Schedule



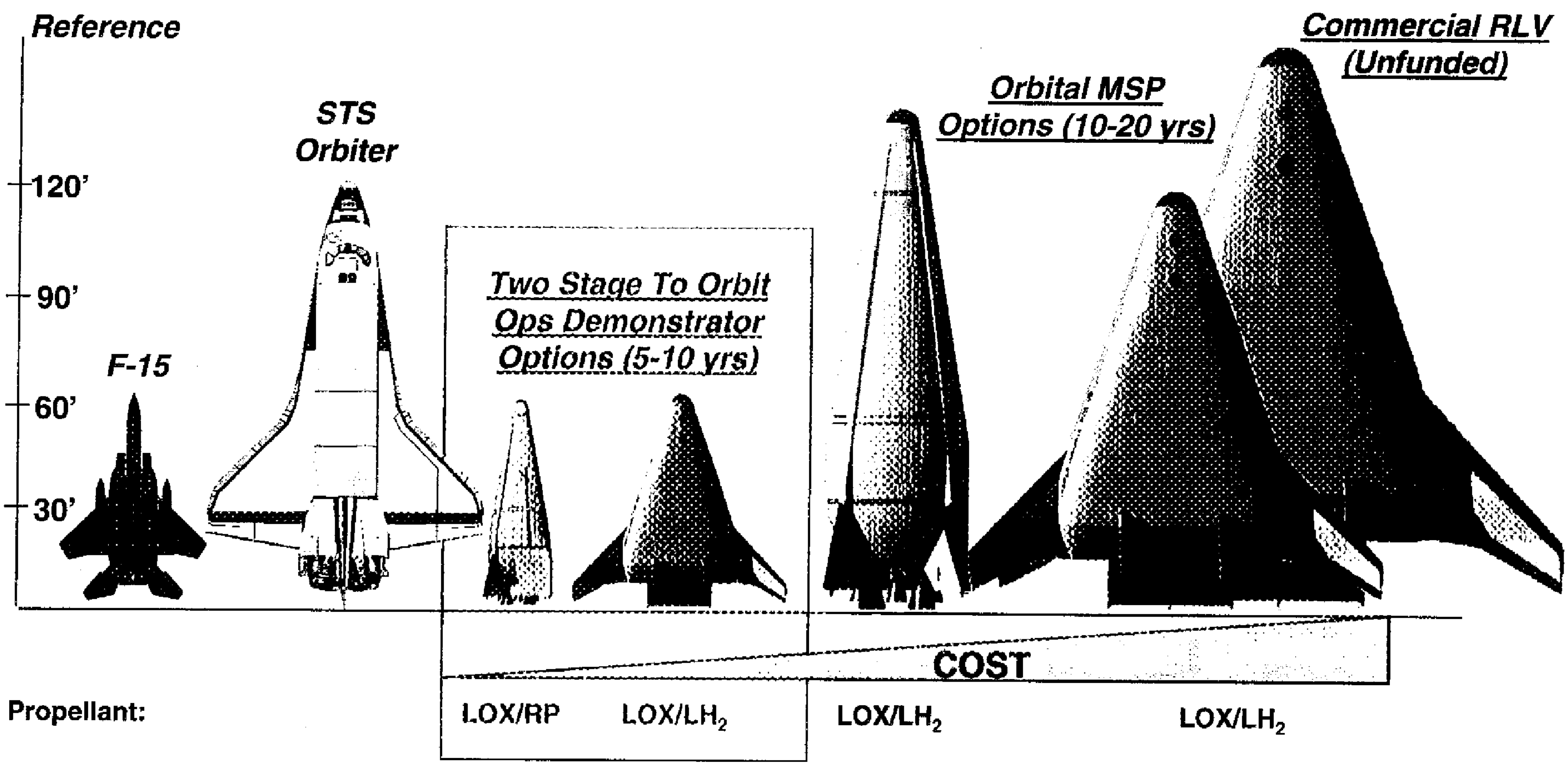
USAF Leveraging Ongoing NASA X-Vehicle Programs

	X-33	X-34	X-38 (X-CRV)	X-37
Mission:	SSTO Technology	Suborbital Air Launch Technology	Space Station Crew Return (ESA Lift Variant)	Next Generation Space Transportation Technology
Funding	$980M	$60M	$80M + $600M	Cooperative Agreement NASA $70M, AF $16M, Boeing $75M
Flight Regime	~Mach 13	~Mach 8	On-Orbit & Reentry	On-Orbit & Reentry
1st Flight:	March 2000	1999	2001	2002
Technologies:	Airframe, LOX/LH_2 Propulsion, etc.	Operations, LOX/RP Propulsion, etc.	Crew Interface, Human factors, etc.	Operations, Payload, H_2O_2 / RP Propulsion etc.
Potential AF Benefits	Technology for Military Spaceplane	Operations for Military Spaceplane	Help Identify Crew Roles & Responsibilities, Recoverable Upper Stage Technology	Potential to Address Space Maneuver Vehicle Technologies & Ops

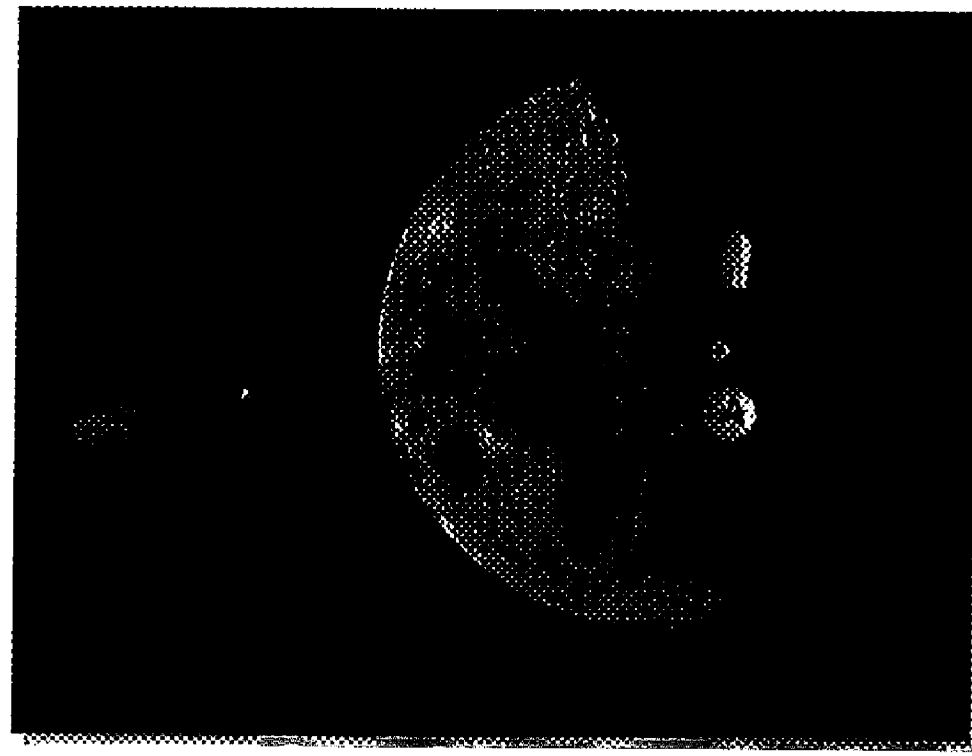
Low Cost / Low Risk Demonstrator Is Affordable Alternative To Large Orbital System

Boeing & Lockheed-Martin Concepts



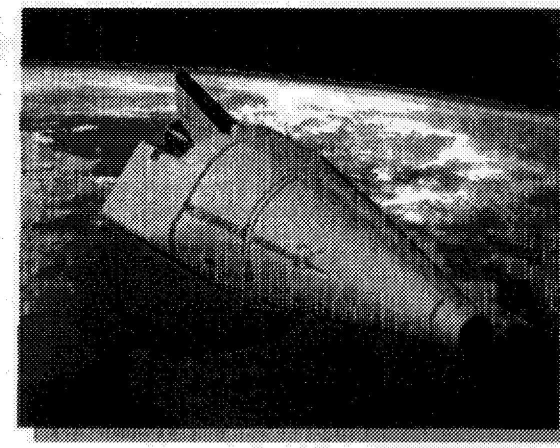
Space Surveillance

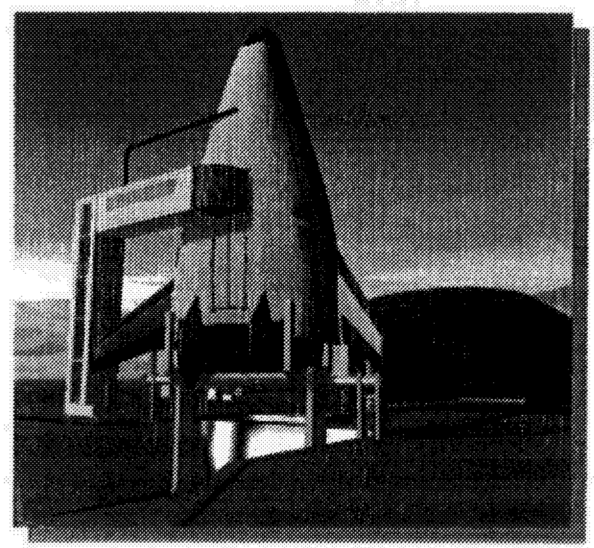
- **Space Object Identification**
  - Multiple sensor capability
  - Co-orbit
  - Optimized fly-by (lighting, angles, position, etc.)



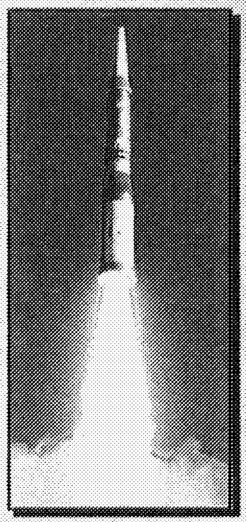
Where Are We?

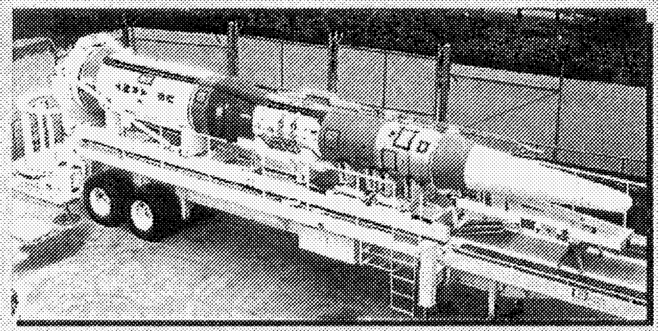
- Requirements Documentation Proceeding
- Developing Acquisition Strategy
  - Leveraging NASA Technology
  - Phased Approach
  - Building AF Demonstrator Technology Roadmap
- Focus 1st on Demonstrator
  - Low risk TSTO "Pop-Up" Approach
  - Potential for Cooperation with NASA
- Pace, Cost & Direction of MSP Program Depends on
  - Degree of NASA & AF cooperation
  - AF decisions (via FY00 POM) on funding & priorities
  - Validation of AFSPC requirements

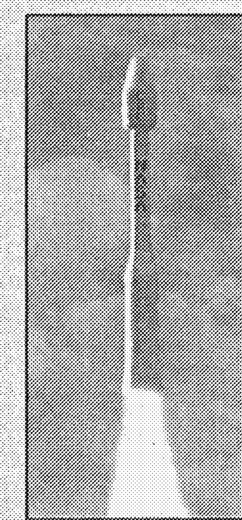


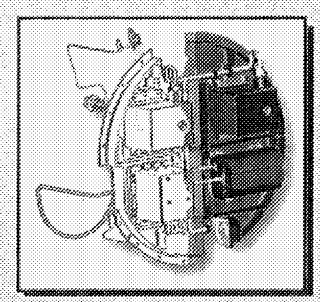


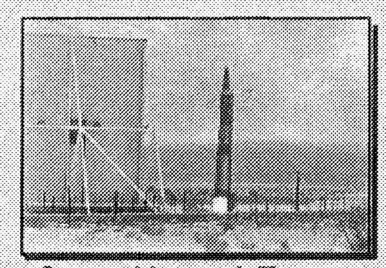
COLEMAN AEROSPACE VEHICLE SYSTEMS

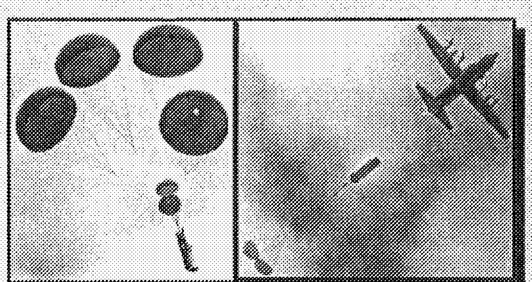

Hera

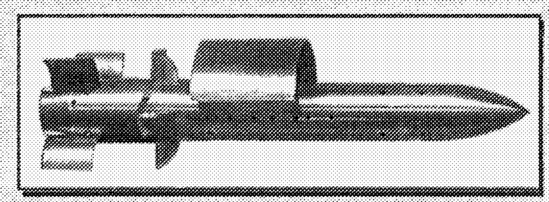

TMD Targets Integration


NASA SELVS


GPS/INS
Range Safety
Tracking System

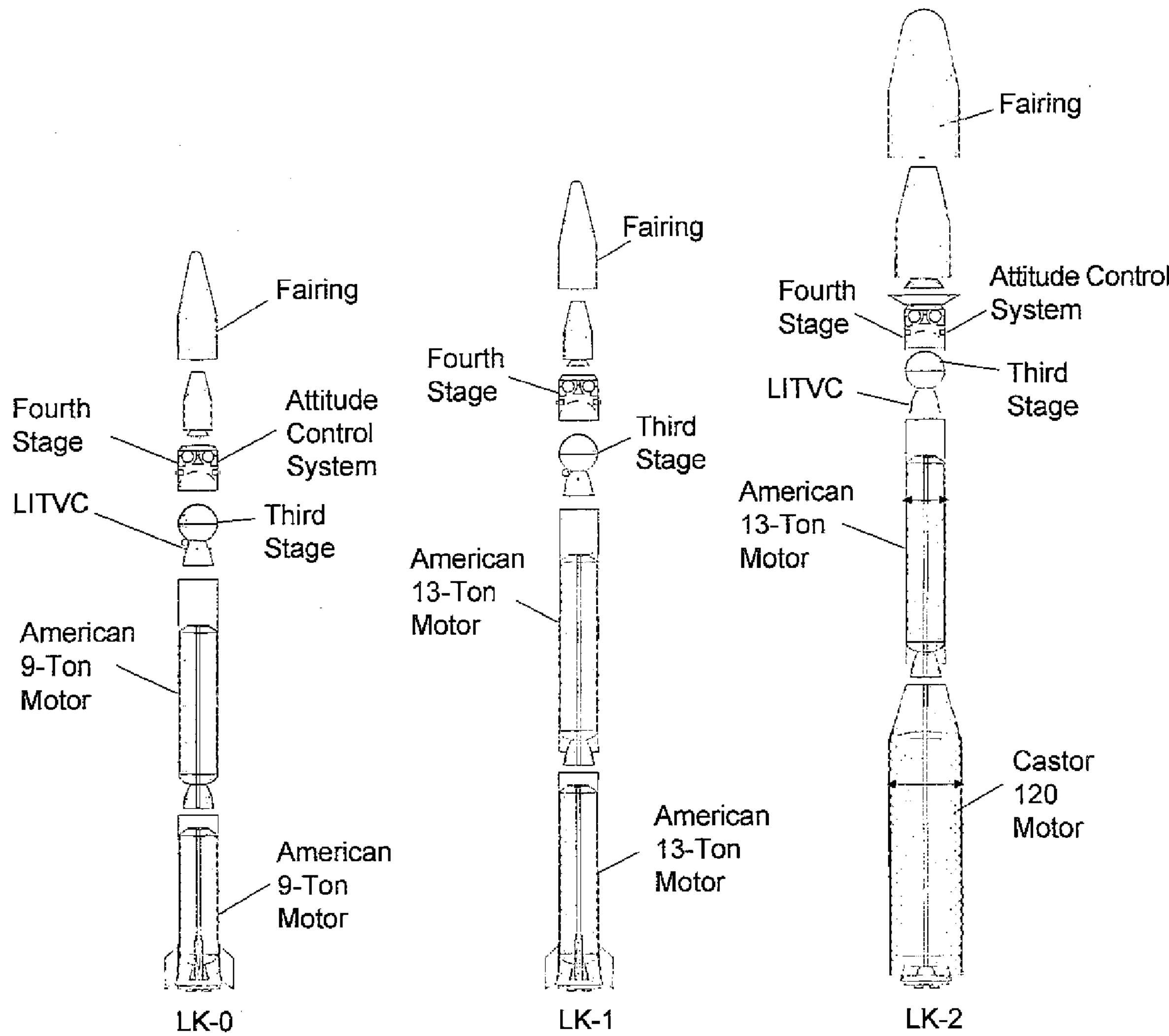

Ground Launch Targets


Air Launch Targets

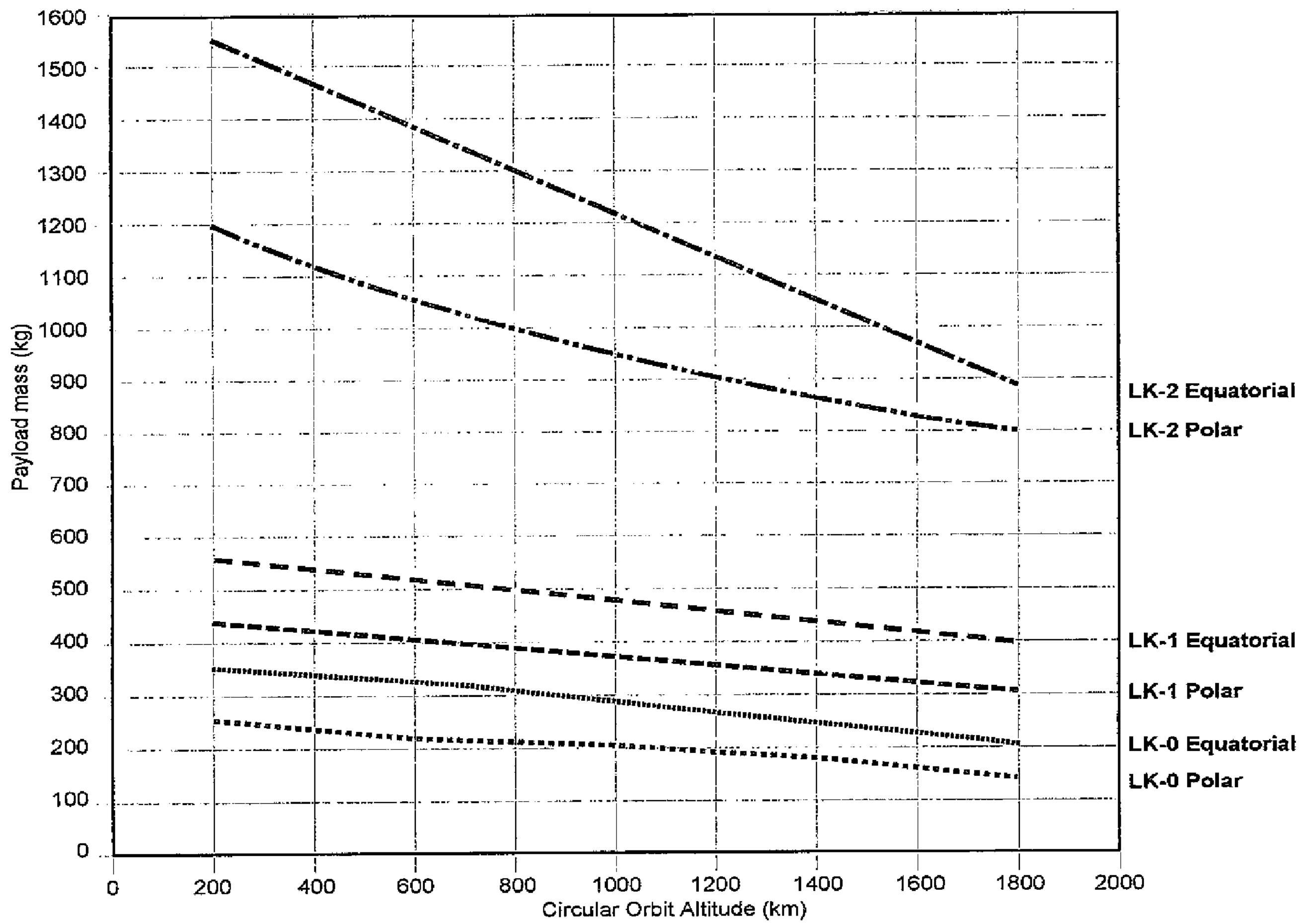

Small Tactical Aerospace Vehicles

Coleman Aerospace conducts research and development and provides products and launch services associated with missile and space vehicle systems

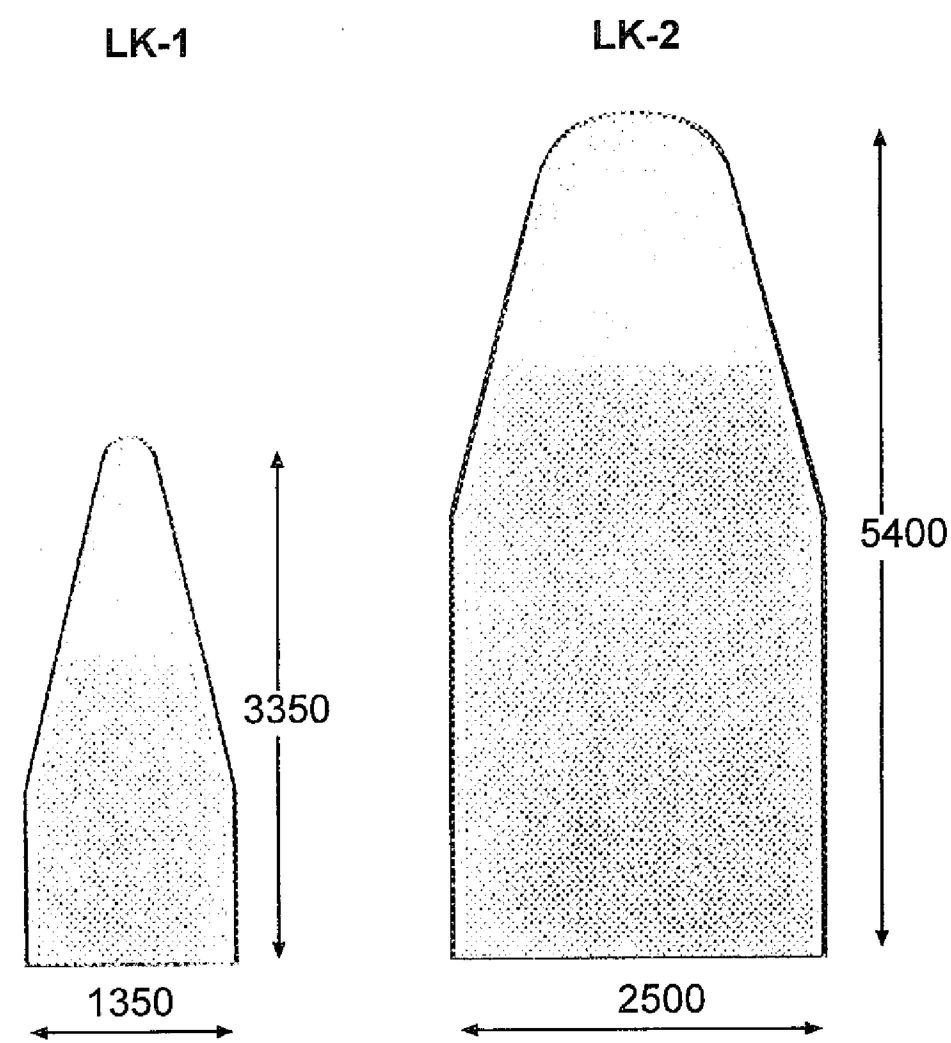
LEOLINK FAMILY OF VEHICLES



LEOLINK VEHICLES ACCOMMODATE PAYLOADS UP TO 1500 KG



PAYLOAD ENVELOPES



LEOLINK TEAM

- Coleman Aerospace Company
- Israeli Aircraft Industries
- Matra Marconi Space

STATUS

- LK-0 is approved by NASA for use under the SELVS II contract
- LK-1 booster has been ground tested, and is scheduled for flight test in 2001
- LK-2 is conceptual

ORBITAL/SUB-ORBITAL PROGRAM

SMC/TEB

Major Steve Buckley

Overview

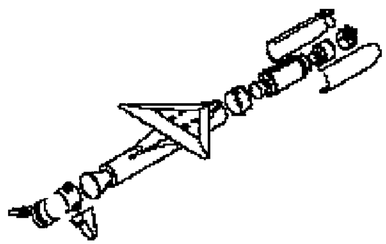
- OSP
- Objectives
- The Concept
- The Program
- OSP SLV Description
- Hybrid Description
- Complex Sub-orbital Description
- Simple Sub-orbital Description
- Launch Support Concept

Launch Test Program Objectives

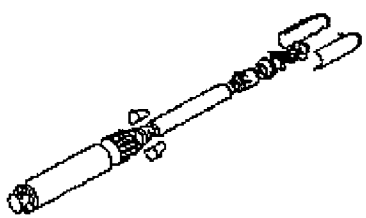
- Use Excess ICBM Assets and Proven Launch Vehicles to:
  - » Provide Cost-Effective, Highly Reliable Launch Services for Orbital and Ballistic Launch Missions
    - Total Cost < $12 Million (Goal)
    - Launch Reliability > 95%
  - » Support Wide Range of Payloads and Orbits
  - » Provide Quick Turn "One-Stop" Launch Service Support
    - Booster Selection, Payload Integration, Launch, and Data Reduction Services

Concept

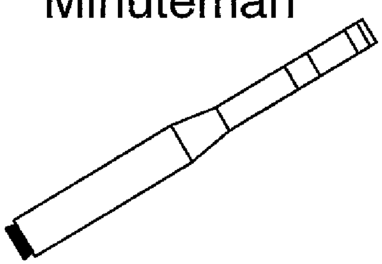
Pegasus



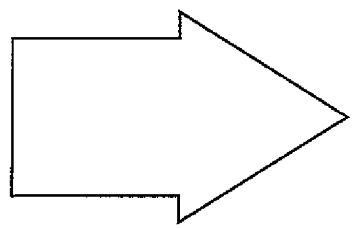
Taurus



Minuteman

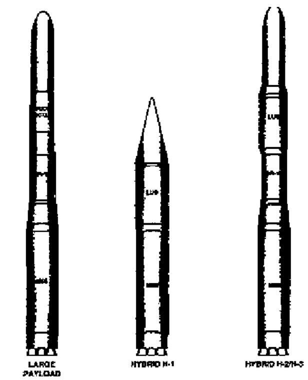


Low Risk
Adapt Proven Designs
To Achieve Launch
Requirements



Low Cost
Use Pegasus, Taurus &
Minuteman Experience
to Minimize Development

OSP Designs



Ballistic Designs

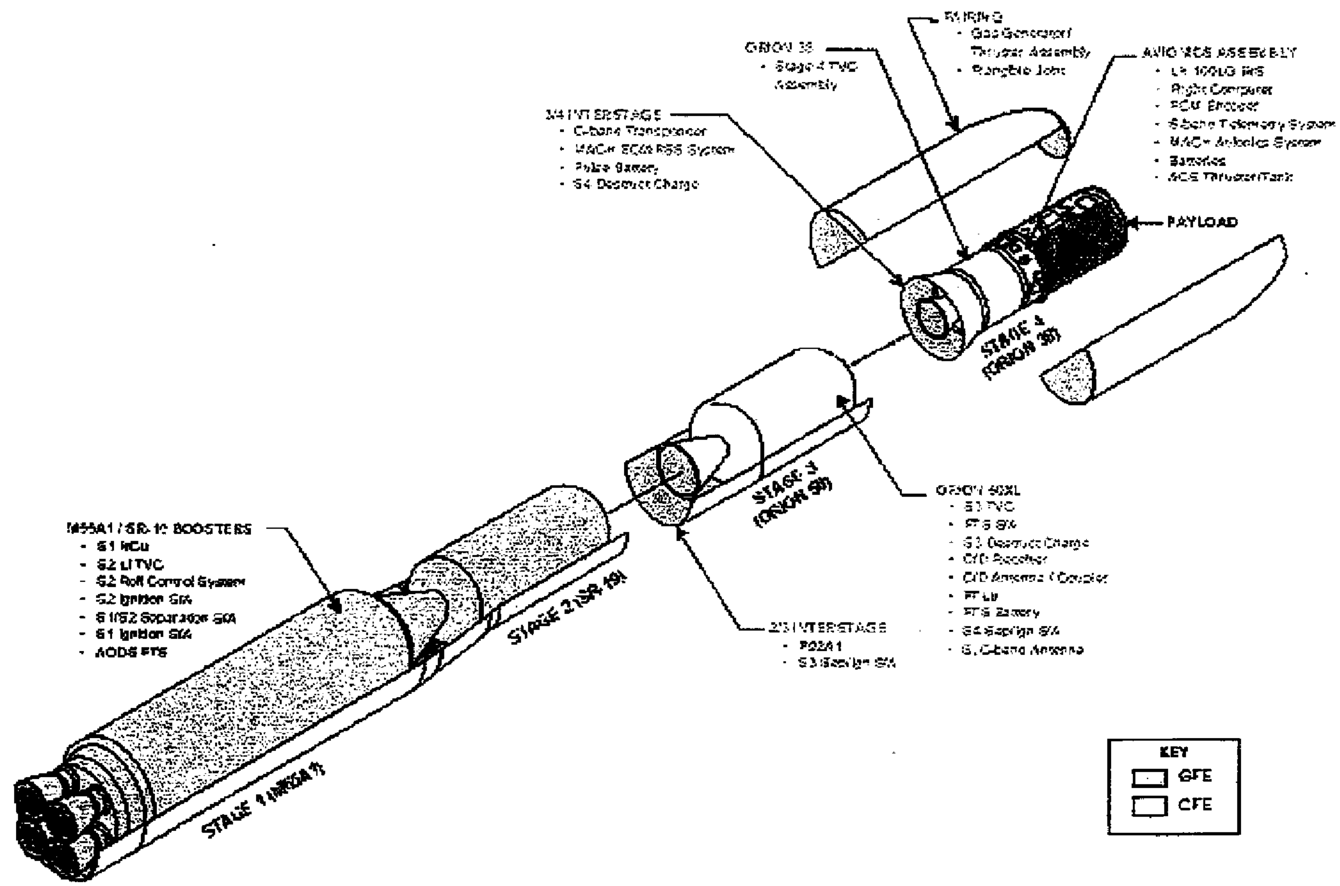
Orbital / Sub-Orbital Program

- Program Elements
  - » Orbital
    - – Large Payload
    - – Hybrid
  - » Sub Orbital
    - – Complex Payload
    - – Single RV

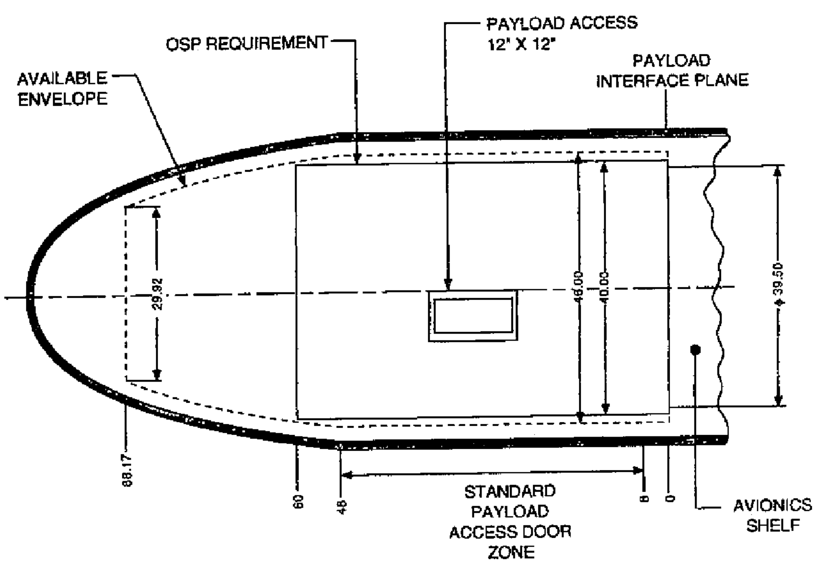
The Orbital Program Element

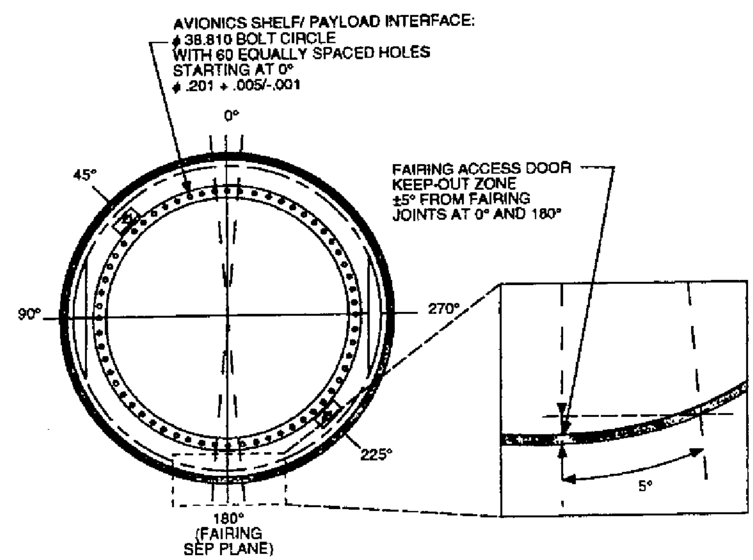
- The OSP SLV for orbiting small satellites

The OSP Small Launch Vehicle



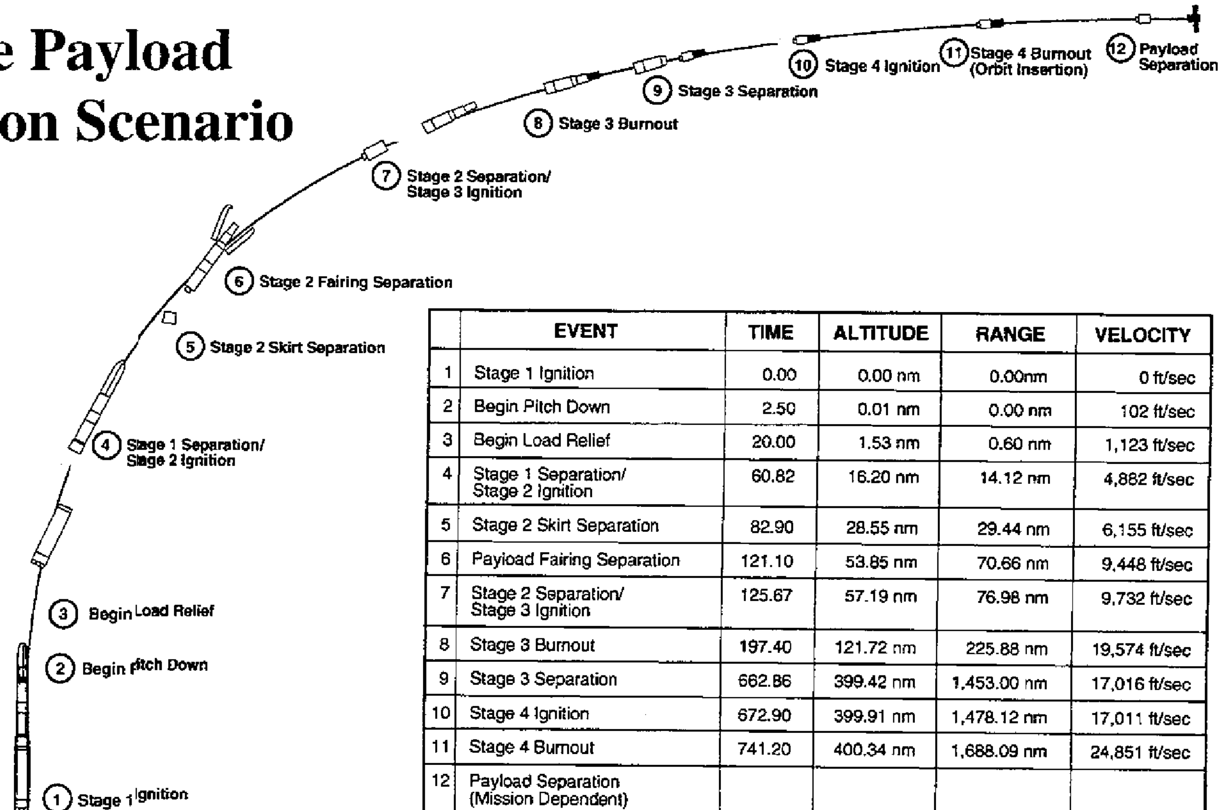
Payload Envelop
Orbital Configuration





Typical Orbital Flight Profile

- **Large Payload Mission Scenario**

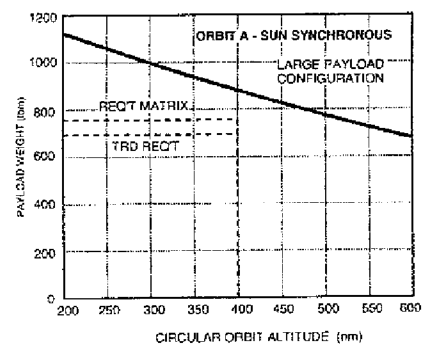


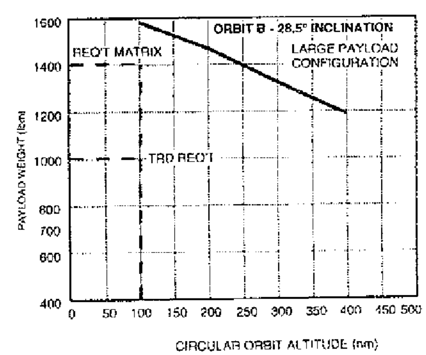
	EVENT	TIME	ALTITUDE	RANGE	VELOCITY
1	Stage 1 Ignition	0.00	0.00 nm	0.00nm	0 ft/sec
2	Begin Pitch Down	2.50	0.01 nm	0.00 nm	102 ft/sec
3	Begin Load Relief	20.00	1.53 nm	0.60 nm	1,123 ft/sec
4	Stage 1 Separation/ Stage 2 Ignition	60.82	16.20 nm	14.12 nm	4,882 ft/sec
5	Stage 2 Skirt Separation	82.90	28.55 nm	29.44 nm	6,155 ft/sec
6	Payload Fairing Separation	121.10	53.85 nm	70.66 nm	9,448 ft/sec
7	Stage 2 Separation/ Stage 3 Ignition	125.67	57.19 nm	76.98 nm	9,732 ft/sec
8	Stage 3 Burnout	197.40	121.72 nm	225.88 nm	19,574 ft/sec
9	Stage 3 Separation	662.86	399.42 nm	1,453.00 nm	17,016 ft/sec
10	Stage 4 Ignition	672.90	399.91 nm	1,478.12 nm	17,011 ft/sec
11	Stage 4 Burnout	741.20	400.34 nm	1,688.09 nm	24,851 ft/sec
12	Payload Separation (Mission Dependent)				

TM13809.007

OSP Large Payload Capabilities

- **Orbits**
  - » **Minimum Performance Sun Synchronous 400 nm**
    - – **750 Pounds Mass**
- **Insertion**
  - » **Pointing Accuracy 4.0 Degrees**
  - » **Altitude +/- 50 nm**
  - » **Inclination +/- 0.2 Degrees**
- **Maneuvering and Command Capabilities to Deploy Multiple Payloads**





Orbital Enhanced Capability Options (1 of 3)

- Increased Payload Volume (50” Dia, 60” Length)
  - Fairing Outside Diameter 54” - 50” Interface Ring
- Payload Separation System
  - Pegasus System - 38” Separation System Baseline - Others Optional
- Enhanced Insertion Accuracy +/- 10nm +/- 0.1^{o}
  - Use Pegasus Hydrazine Auxiliary Propulsion System to Circularize Orbit
- Conditioned Air
  - Taurus-Proven System with Fly-Away Ducts
- Nitrogen Purge
  - Pegasus Shroud Standard Feature

Orbital Enhanced Capability Options (2 of 3)

- Payload Access Panel
  - » Accommodated by Pegasus Fairing with Drawing/ICD Change
- Navigation Data
  - » Orbital-Developed GPS Position Beacon (GPB) Flown on MTD-2
- Enhanced Telemetry (2Mbps)
  - » Baseline Encoder Accommodates UP to 10 Mbps - 10^{-6} BER at 2100 nm Slant Range
- Enhanced Contamination Control
  - » HEPA Filter Added to Payload Air Condition System

Orbital Enhanced Capability Options (3 of 3)

- Softride for Small Satellites (SRSS)
  - » Passive isolation system designed by AFRL through SBIR contract with CSA Engineering
    - Entire system weighs no more than 25 pounds
    - Replaces bolts that attach space vehicle to launch vehicle
    - Can be used above or below separation system
  - » Approximate cost - $200K if baselined for OSP

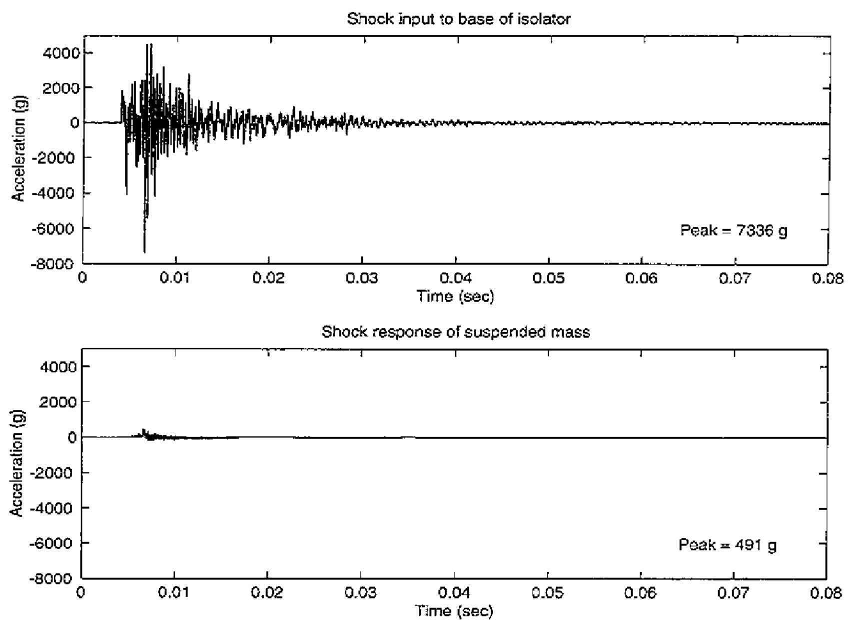
Soft Ride for Satellites

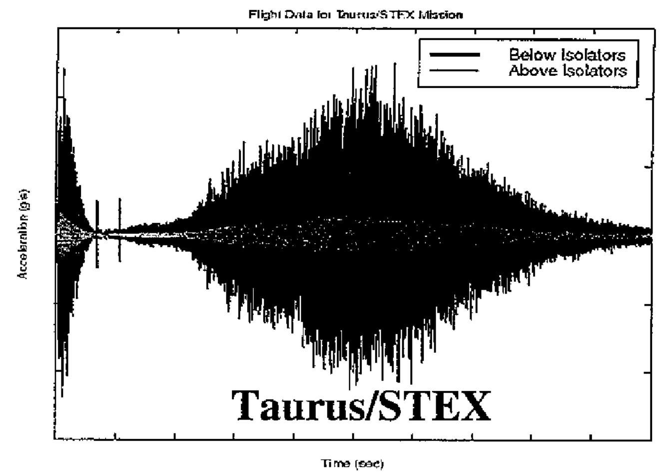
POC: Dr. Dino Sciulli (505) 846-8256, Mr. Eugene Fosness (505) 846-7883

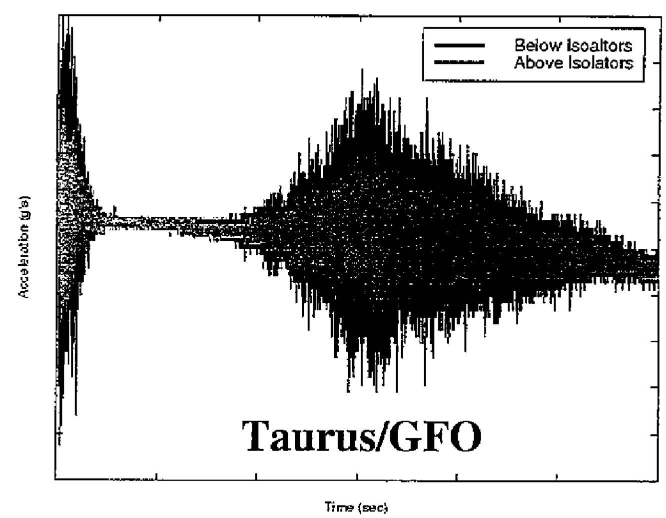
Taurus - $150K,   OSP - $200K

Athena II - $160K

Phase III Task Order Contract in Place for Rapid Study, Design, and Manufacture







Typical Program Costs

- Typical Costs

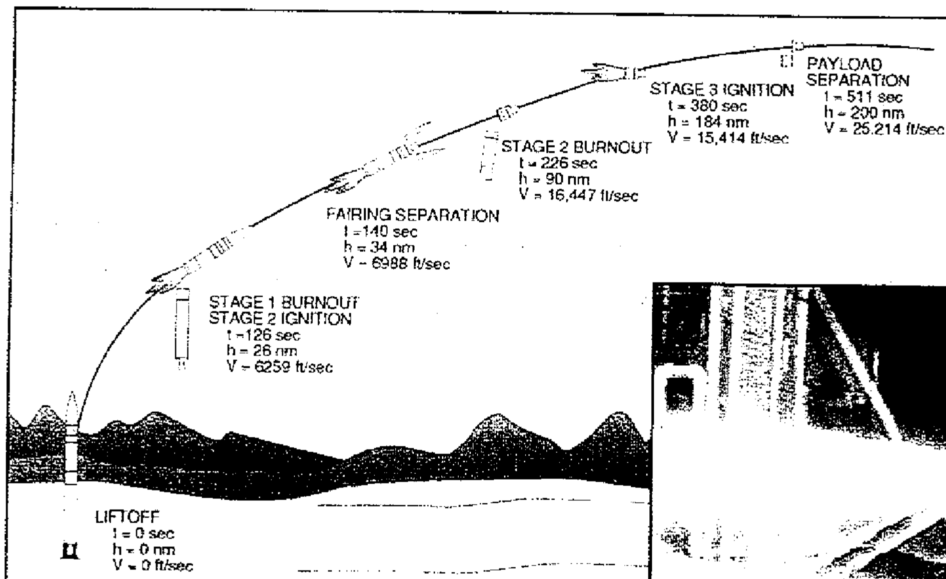
» Vehicle	$ 9,500,000	- Includes Msn Success Payment
» SE/TA	$ 750,000	- $600K to $1,000K
» Range	$ 750,000	- $600K to $1,000K
» Payload Int	$ 250,000	- $250K to $500K Based On Options
» Booster Refurb	$ 500,000	
» Shipping	$ 250,000	- $50K to $250K
» Program Mgmt	$ 500,000	
» TOTAL	$12,500,000	

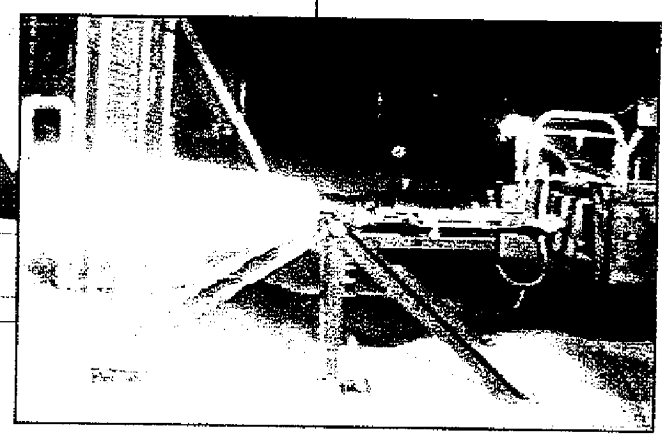
The Hybrid Program Element

- Flight test opportunity for developmental upper stages

Hybrid Launch Mission H-1
NASA's Upper Stage Flight Experiment

- Minuteman / NASA Liquid Upper Stage Hybrid 1
  - » Purpose - Flight Test of Advanced Liquid Upper Stages
  - » Uses M55 Minuteman Stage 1/2 and LUS
- Conduct Flight Test





Hybrid Launch Mission H-2 & H-3

- Minuteman / NASA Liquid Upper Stage Hybrid 2 & 3
  - » Purpose - Demonstrate Capability to Perform Flight Testing of Advanced Liquid Upper Stages
  - » Uses M55 Minuteman Stage One and SR19 Stage 2 with LUS
  - » The Liquid Upper Stages will be Different Configurations
- Details of Liquid Upper Stages will be Included in MRD

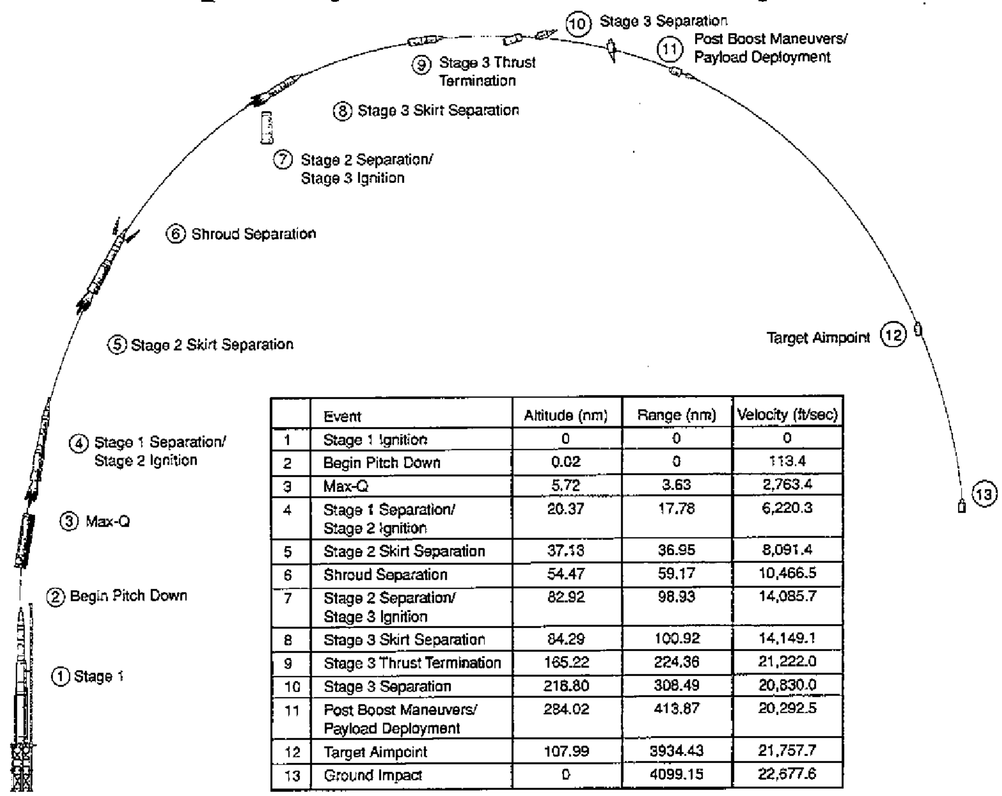
NO MISSION PLANNED YET

The Complex Sub-orbital Program Element

- Support sub-orbital missions that require an aerodynamic fairing

Sub-Orbital Complex Payload

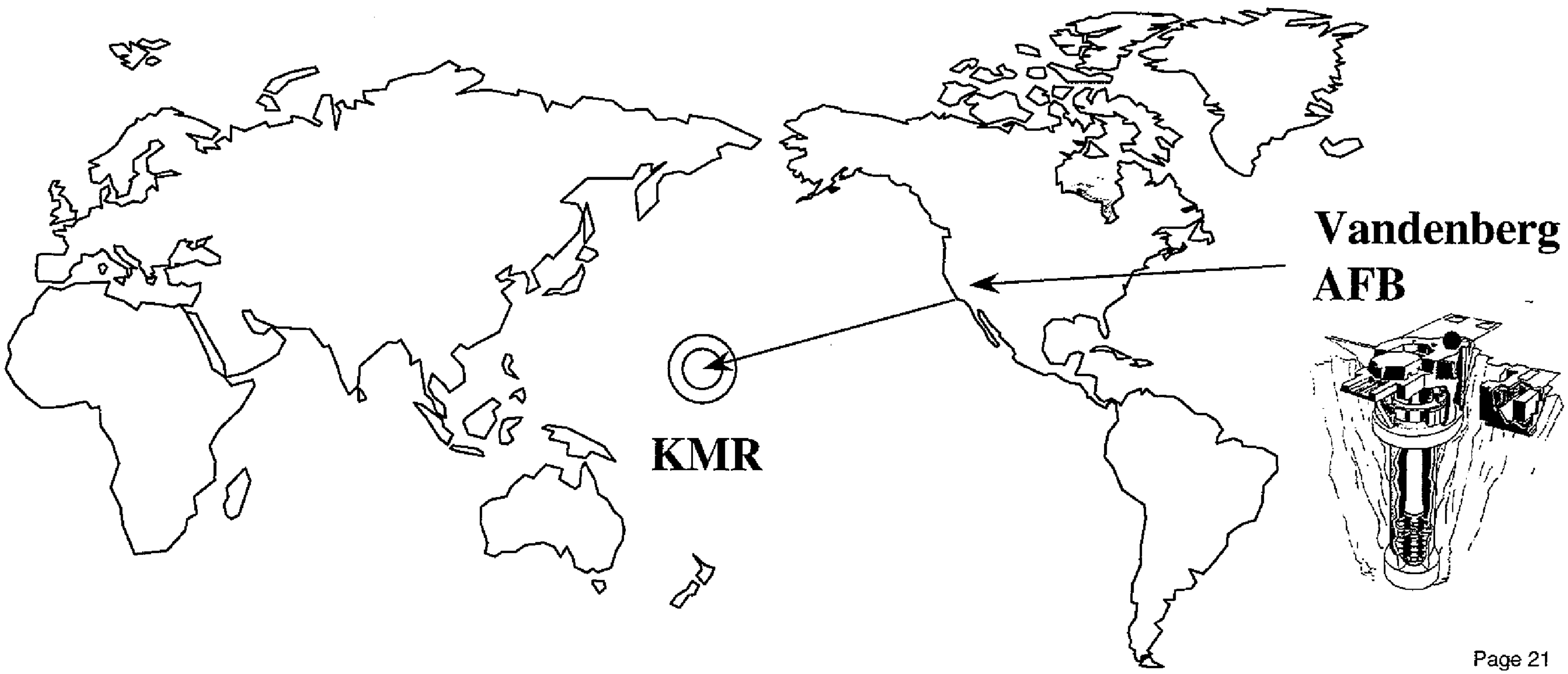
- **Minuteman II 3 Stage Booster**
  - » **Deliver Multiple Payloads on ICBM Trajectories**



	Event	Altitude (nm)	Range (nm)	Velocity (ft/sec)
1	Stage 1 Ignition	0	0	0
2	Begin Pitch Down	0.02	0	113.4
3	Max-Q	5.72	3.63	2,763.4
4	Stage 1 Separation/ Stage 2 Ignition	20.37	17.78	6,220.3
5	Stage 2 Skirt Separation	37.13	36.95	8,091.4
6	Shroud Separation	54.47	59.17	10,466.5
7	Stage 2 Separation/ Stage 3 Ignition	82.92	98.93	14,085.7
8	Stage 3 Skirt Separation	84.29	100.92	14,149.1
9	Stage 3 Thrust Termination	165.22	224.36	21,222.0
10	Stage 3 Separation	218.80	308.49	20,830.0
11	Post Boost Maneuvers/ Payload Deployment	284.02	413.87	20,292.5
12	Target Aimpoint	107.99	3934.43	21,757.7
13	Ground Impact	0	4099.15	22,677.6

Complex Payload Capabilities

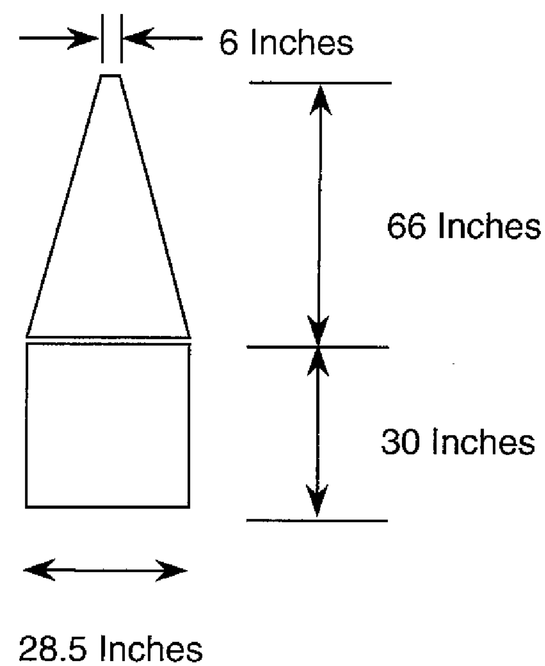
- **Vandenberg LF 06 Launch to Kawajalein Atoll.**
  - » **Re-entry Angle 20 to 40 Degrees**
  - » **Multiple Payloads Possible**



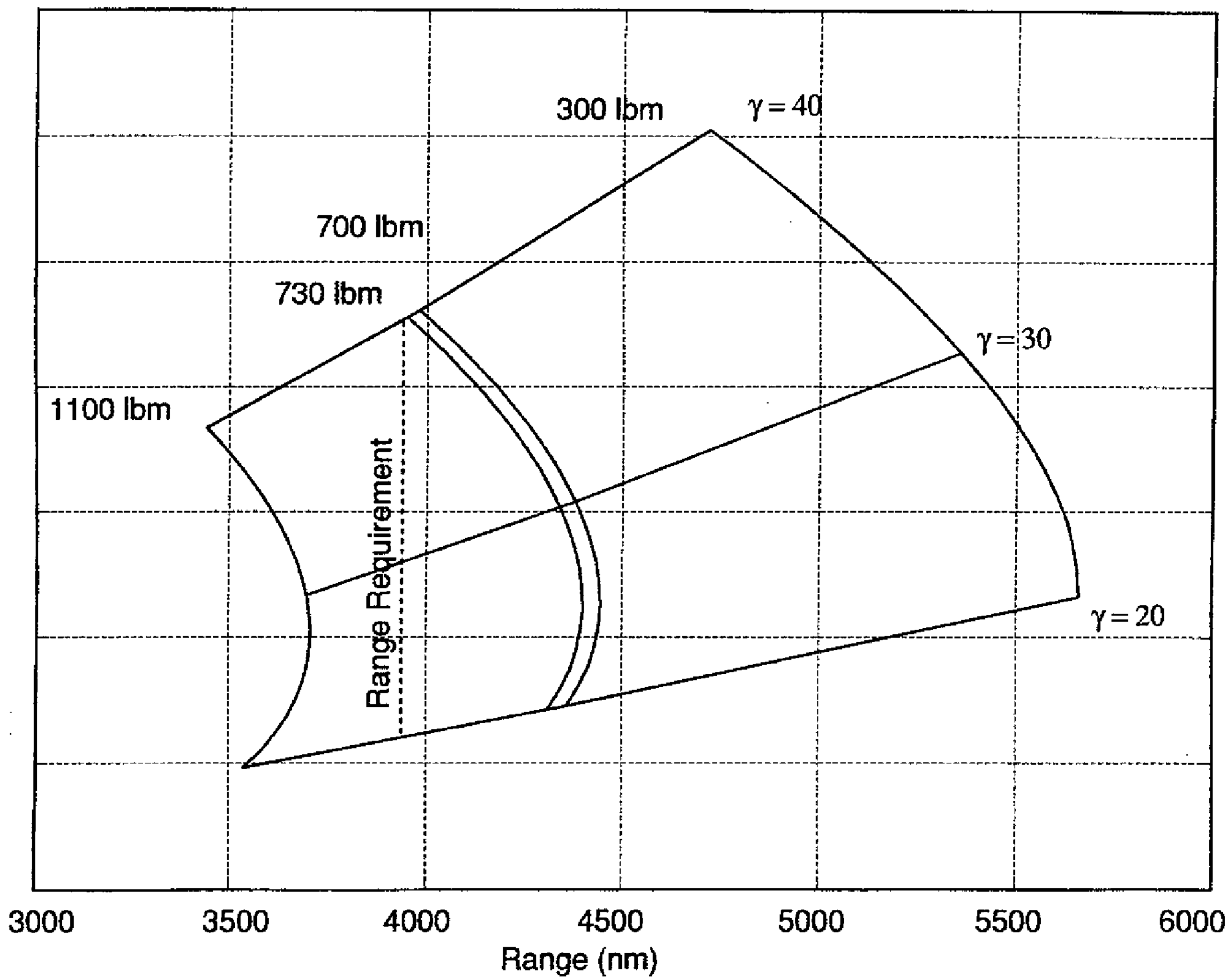
Complex Payload Capabilities

- **Payload Envelope**
  - » Up To 8 Canisterized Payloads 5.7" x 25"
  - » GFP to OSP Contractor
- **Mass Properties**
  - » RV 500 Pounds Mass
  - » Rigid Targets 40 Pounds Mass
  - » Canisterized Targets 60 Pounds Mass
  - » Non-Deployed Hardware
  - » Total Payload Weight Range
    300 lbm to 1100 lbm

Initial Measurements



Complex Payload
Throw Weight Performance

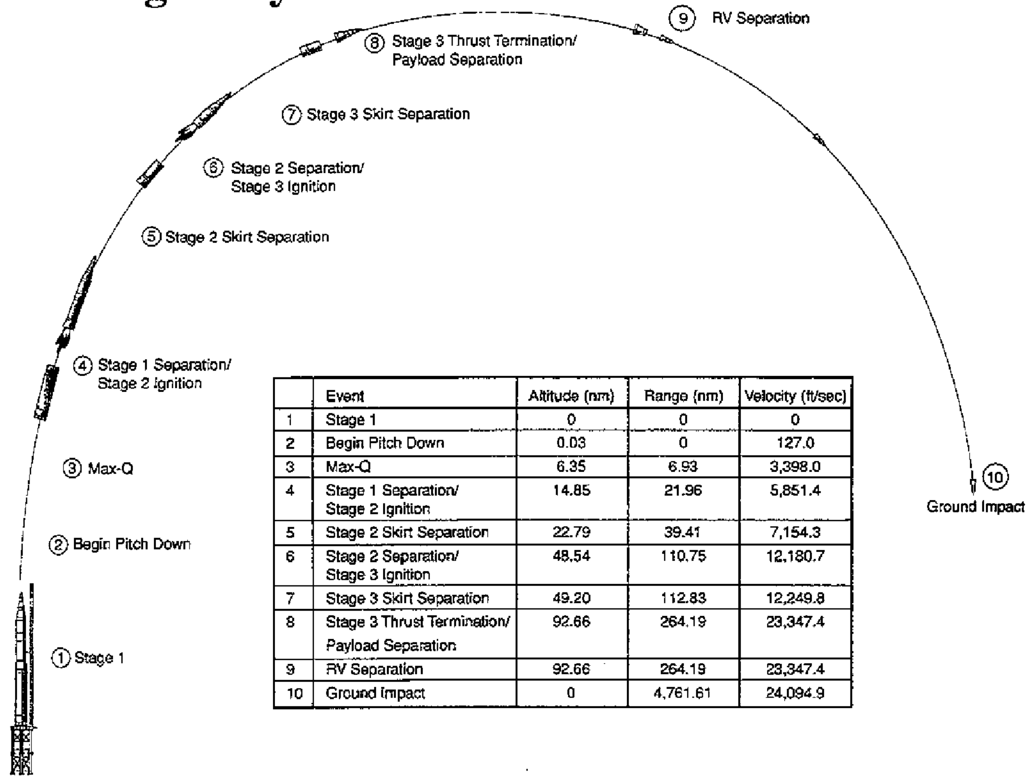


The Simple Sub-orbital Program Element

- Support sub-orbital missions that do not require an aerodynamic fairing

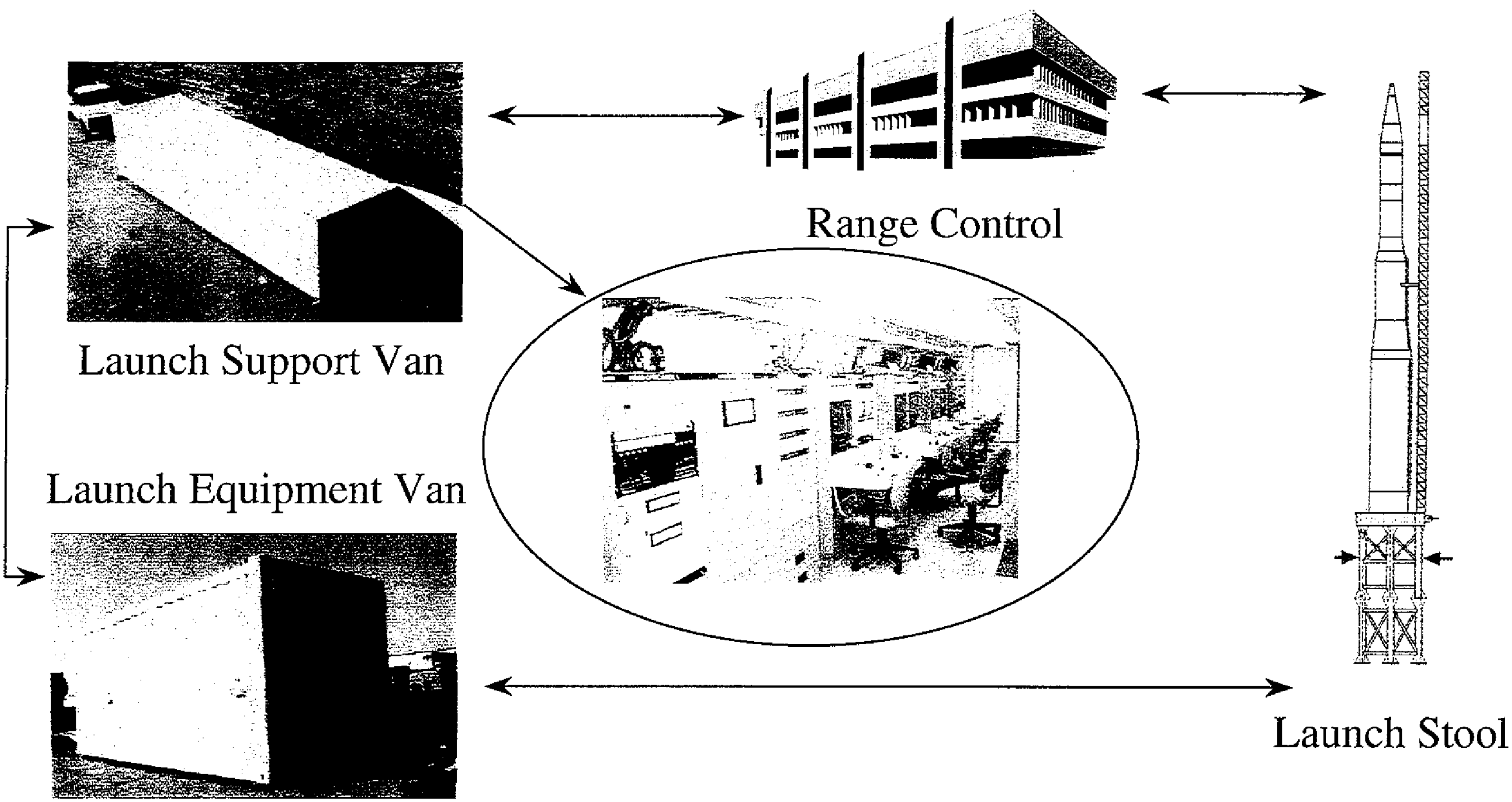
Sub-Orbital Single RV Payload

- **Minuteman II Stage 1&2, Minuteman III Stage 3**
  - » **Deliver Single Payload in Mark 11 Aeroshell**



	Event	Altitude (nm)	Range (nm)	Velocity (ft/sec)
1	Stage 1	0	0	0
2	Begin Pitch Down	0.03	0	127.0
3	Max-Q	6.35	6.93	3,398.0
4	Stage 1 Separation/ Stage 2 Ignition	14.85	21.96	5,851.4
5	Stage 2 Skirt Separation	22.79	39.41	7,154.3
6	Stage 2 Separation/ Stage 3 Ignition	48.54	110.75	12,180.7
7	Stage 3 Skirt Separation	49.20	112.83	12,249.8
8	Stage 3 Thrust Termination/ Payload Separation	92.66	264.19	23,347.4
9	RV Separation	92.66	264.19	23,347.4
10	Ground Impact	0	4,761.61	24,094.9

Launch Support Concept



Launch Support Concept

- Launches will be performed from Combination Launch Stool and Umbilical Tower
- Portable Launch Support Van (LSV) and Launch Equipment Van (LEV) Will Contain Launch Support Equipment and Range Interface Electronics

Existing OSD Direction

- OSD Memo dated 28 May 1996
  - » Granted conversion of 5 MM IIs into SLVs
  - » Requested report on booster conversion and JAWSAT launch to "ensure cost-effective use of government assets without inhibiting the growth and development of the U.S. commercial launch industry."

- OSP contract was put in place
  - » Fixed price contract
    - – Removed uncertainty about cost effectiveness issue
  - » Demonstration launch (FalconSat) then pure launch service
  - » 18 month period of performance
  - » 5-year contract life

Spaceport Contracted Agencies

- Alaska Aerospace Development Corporation (AADC)
- Spaceport Florida Authority (SFA)
- Spaceport System International (SSI)
- Virginia Commercial Space Flight Authority / Center for Commercial Space Infrastructure (VCSFA/CCSI)

Space Launch Program

- Space Launch Program Has Five Components
  - » Launch Vehicle - Initial Launch Capability 3rd Quarter 1999
  - » Spaceport - Contract In Place
  - » Soft Ride for Small Satellite - Design Completed
  - » Booster Refurbishment - Schedule Varies by Project
  - » Transporter/Erector

Cost / Funding Procedures

- Customer Prepares MRD in Conjunction with SMC/TE Functional Lead
  - » Services Provided as Required from "Menu"
- Typical Events
  - » Customer Develops Requirement
  - » SMC/TE OSP Conducts Feasibility Studies
  - » Defines Funding Requirements and Schedule
  - » Funds Transferred to SMC/TEB
  - » Mission Manifested
  - » Delivery Order Let
  - » Develop Master Mission Schedule & Spend Plan
  - » Execute Launch Services

Questions?

- Maj Tony Rivera—Ballistic Launch
  (505) 846-5346
- Maj George Stoller—Orbital Launch Support
  (505) 846-5952

Rideshare Conference

April 15-16, 1999

NASA Headquarters

Kennedy Space Center

Organization

and

Small Spacecraft Launch Services

Albert Sierra

Darren Beddel

Agenda

NASA ELV Program

NASA Headquarters ELV Requirements Products and Services

KSC Organization Overview

Mission Integration Team (MIT) Philosophy/Roles

Existing Dual Ride and Secondary Payload Options

Previously Flown Secondary Payloads

Potential Missions for Dual or Secondary Payloads

Key Contacts

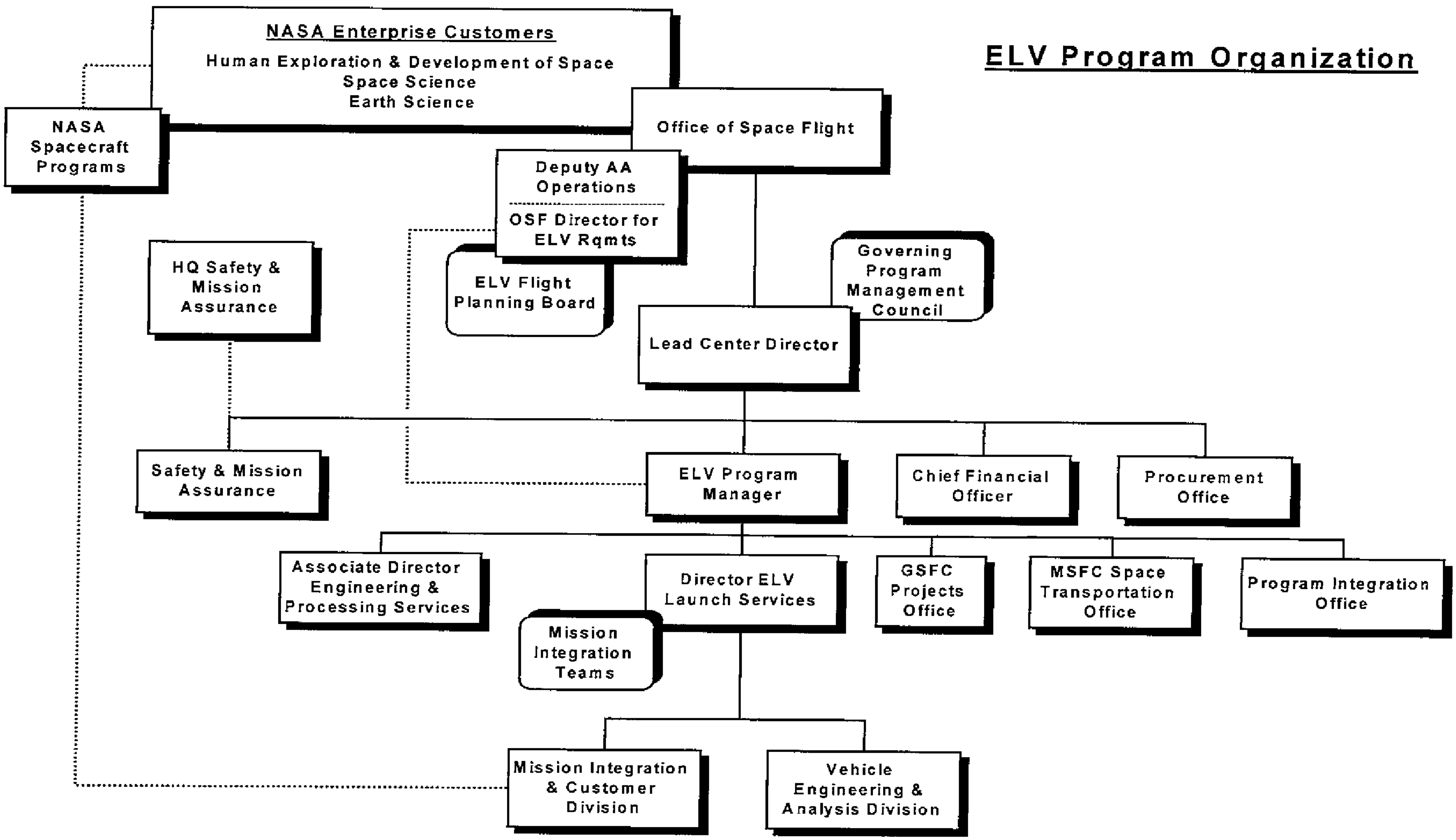
Secondary Payload Contact List

KSC ELV Program Objectives

- NASA's Lead Center for the Acquisition and Management of Expendable Launch Vehicle Services
  - NASA's ELV Program was previously distributed across multiple NASA Centers by vehicle class and program function.
  - October, 1997 - NASA authorized the establishment of the Lead Center for the Acquisition and Management of the Expendable Launch Vehicle Launch Services at KSC
  - KSC has established an organization to fulfill this responsibility
- Provide safe, reliable, cost-effective ELV Launches
- Maximize Customer Satisfaction
- Perform Advanced Payload Processing Capability Development

ELV Program Organization

EXPENDABLE LAUNCH VEHICLES



ELV REQUIREMENTS
POLICY

- CSLA AGREEMENT WITH INDUSTRY
- DEVELOP/UPDATE NASA POLICY DIRECTIVES(NPD) ON ELV MANAGEMENT
- DEVELOP/COORDINATE INTERNATIONAL MOA'S RE: SECONDARY PAYLOADS (I)
- REVIEW AND SEEK INDEMNIFICATION AUTHORITY (G)
- COORDINATE/REVISE ELV ACQUISITION GUIDELINES (H)
- SUPPORT REVIEW/COMMENT ON PROPOSED LEGISLATION (G)
- REVIEW AND REVISE ELV MANPOWER LEVELS / SKILLS MIX
- LEVEL OF TECHNICAL INSIGHT AND OVERSIGHT EMPLOYED
- ALTERNATIVE WAYS OF DOING BUSINESS

ELV REQUIREMENTS
INTERNAL CONTACTS

- ADMINISTRATOR
- DEPUTY ADMINISTRATOR (TECHNICAL)
- COMPTROLLER
- ASSOCIATE ADMINISTRATORS AND DEPUTIES (codes S / Y / R / M / H / I)
- GENERAL COUNCIL
- OSS FLIGHT PROJECTS DIRECTOR
- OMTPE FLIGHT PROJECTS DIRECTOR
- OMTPE NOAA PROGRAM MANAGER
- OSF SPACE STATIONMANAGER
- PAYLOAD PROGRAM MANAGERS
- CENTER DIRECTOR

ELV REQUIREMENTS
EXTERNAL CONTACTS

- ASSISTANT SECRETARY OF AIR FORCE (ACQUISITIONS)
- ASSISTANT SECRETARY OF AIR FORCE (SPACE POLICY & PLANS)
- DOD SS&T DIRECTOR
- DIRECTOR OCST
- BASE COMMANDERS (45TH & 30TH)
- OSTP SCIENCE & TECHNOLOGY
- OMB NASA BUDGET EXAMINERS
- CONGRESSIONAL STAFF (HOUSE / SENATE)
- ELV INDUSTRY (VICE PRESIDENT AND SENIOR MANAGER LEVEL)
- SPACECRAFT INDUSTRY (VICE PRESIDENT AND SENIOR MANAGER LEVEL)
- INTERNATIONAL ELV D.C. REPS (NASDA / ARIANE)
- AIAA DIRECTOR
- IAA SMALL SPACECRAFT TECHNOLOGY COMMITTEE
- SENIOR INTERNATIONAL AGENCY PERSONNEL

ELV REQUIREMENTS
INTERNAL PRODUCTS AND SERVICES

- PROVIDE POLICY FOR OBTAINING OFFICE OF SPACE FLIGHT PROVIDED/ARRANGED SPACETRANSPORTATION SERVICES FOR NASA AND NASA-RELATED PAYLOADS
- PROVIDE POLICY AND DIRECTION TO THE ELV PROGRAM OFFICE AT KSC
  - LAUNCH SERVICES RISK MITIGATION POLICY FOR NASA-OWNED /SPONSORED PAYLOADS
  - TECHNICAL INSIGHT/OVERSIGHT OF ELV LAUNCH SERVICES TO ASSURE MISSION SUCCESS
  - EXPENDABLE LAUNCH VEHICLE (ELV) LAUNCH SERVICES PRELAUNCH REVIEWS
- IDENTIFY, AGGREGATE LAUNCH REQUIREMENTS
  - DEVELOP ACQUISITION STRATEGIES TO MEET REQUIREMENTS
  - IDENTIFY / INITIATE NEW SERVICES
  - ANTICIPATE / RESOLVE LAUNCH CONFLICTS
  - NEGOTIATE / ARRANGE REQUISITE FACILITIES
- CHAIR ELV FLIGHT PLANNING BOARD
  - BASELINE, MISSION LAUNCH PLANNING (VEHICLE / DATE)
  - IDENTIFY / RESOLVE LAUNCH CONFLICTS

ELV REQUIREMENTS
EXTERNAL PRODUCTS AND SERVICES

DOD - PENTAGON

- MOA'S FOR LAUNCH SERVICES SUPPORT
- ANNUAL ELV REQUIREMENTS LETTER
- REQUEST / NEGOTIATE USE OF DOD FACILITIES / RESOURCES
- IDENTIFY AND RESOLVE LAUNCH CONFLICTS
- NEGOTIATE COSTS FOR USAF SERVICES
- REVIEW DOD CONTRACTS AND RFP'S
- COORDINATE PROCUREMENTS / NEGOTIATE MOA
- SERVE AS NASA REP ON STP PAYLOAD REVIEW BOARD
- SERVE AS NASA REP ON DODO LAUNCH INFRASTRUCTURE BOARD
- IDENTIFY AND COORDINATE CONSISTENT NASA/ DOD POLICY FOR COMMERCIAL ACCESS TO EXCESS FACILITIES / SERVICES
- PARTICIPATE IN GAO REVIEWS OF SERVIOCES PROVIDED BY NASA

ELV REQUIREMENTS
FOREIGN LAUNCH VEHICLE POLICY

- NATIONAL SPACE TRANSPORTATION POLICY REQUIRES ALL US GOVERNMENT PAYLOADS BE LAUNCHED ON VEHICLES MANUFACTURED IN US
  - UNLESS EXCEPTION BY PRESIDENT
  - OR INTERNATIONAL COOPERATIVES WHERE LAUNCH ON NO-FUNDS EXCHANGED BASIS WITH FOREIGN PARTNER
- OSTP IS RESPONSIBLE FOR FACILITATING INTERAGENCY REVIEW OF ANY EXCEPTIONS
- INTERAGENCY AGREEMENT THAT POLICY NEEDS REVIEW
- NASA IS CONDUCTING AN INTERNAL REVIEW OF THE POLICY
- NASA SEEKS TO REFINE DEFINITION OF PAYLOAD TO EXCLUDE INSTRUMENTS OF TBD $$$

ELV REQUIREMENTS
EXTERNAL PRODUCTS AND SERVICES

CONGRESS

- PREPARE / SUPPORT ADMINISTRATOR MEETINGS WITH MEMBERS
- BRIEF STAFFERS ON ELV PROGRAM / RESPOND TO INQUIRES
- RESPOND TO CONSTITUENT CONCERNS
- COMMENT / REVIEW DRAFT LEGISLATION
- DEVELOP CONGRESSIONAL REPORTS

ELV INDUSTRY

- MANIFEST CONFLICT RESOLUTION
- NEGOTIATE / COORDINATE CSLA AGREEMENTS FOR HQ SIGNATURE
- RESPOND TO CUSTOMER SURVEYS
- STATUS ON EXTERNAL ENVIRONMENTS AFFECTING ELVS
- NEW SERVICES TO MEET NEW DEMANDS

INTERNATIONAL

- FACILITATE UNDERSTANDING OF US ELV CAPABILITY
- FACILITATE UNDERSTANDING OFCOOPERATIVE PROCESS WHERE ELV LAUNCH SERVICE IS PROVIDED

ELV REQUIREMENTS
EXTERNAL PRODUCTS AND SERVICES

OMB

- PRESENT NASA INTEGRATED ELV BUDGET
- RESPOND TO INQUIRIES ON ELV COSTS

DOT

- DEVELOP / NEGOTIATE MOA (UELV LICENSE)
- AGENCY FOCAL POINT FOR DOT LIASON ON ELVS
- COORDINATE AGENCY REVIEW OF DOT COMMERCIAL LICENSES / REPORTS / INSURANCE ASSESSMENTS / REGULATIONS
- PARTICIPATE ON COMSTAC WORKING GROUPS

DOE

- SUPPORT INTERAGENCY NUCLEAR SAFETY REVIEW PANEL

OSTP

- SERVE AS NASA ELV REP ON WORKING GROUPS FOR NATIONAL SPACE POLICY
- PROVIDE STATUS ON ELV PROGRAMS AND PROCUREMENTS

ELV REQUIREMENTS
HOW TO GET A NASA LAUNCH SERVICE

- SCIENCE ENTERPRISE AO
  - PROPOSALS TO MEET SCIENTIFIC OBJECTIVES OF THE AGENCY
  - AO PROVIDES GUIDELINES FOR SPACECRAFT AND LAUNCH VEHICLE
- THE PROPOSAL(S) SELECTION ON SCIENTIFIC MERIT
- SCIENCE ENTERPRISE BRINGS THE NEW REQUIREMENT TO THE FLIGHT PLANNING BOARD
- THE NEW REQUIREMENT IS APPROVED BY THE BOARD
  - LAUNCH DATE
  - LAUNCH VEHICLE(S)
  - CO-MANIFEST?
  - LAUNCH SERVICE CONTRACT IN PLACE?
- DIRECTION TO KSC TO PROCURE THE LAUNCH SERVICE
- KSC ACQUIRES AND MANAGES THE LAUNCH SERVICE

ELV AND UPPER STAGES MANIFEST

	CY '99	CY '00	CY '01	CY '02	CY '03	CY '04	CY '05	CY '06
•SMALL CLASS (SC) • PEGASUS (P) - WFF • UELV (UL) • LOW COST BOOSTER (LC) •ATHENA I (AI) •SECONDARY (S)	D/S ORSTED/SUNSAT 2/23 P WIRE - 3/4 UL TERRIERS/MUBLCOM 4/12 T/S ACRIM/KOMPSAT 9/24	△ P HETE II - 1/23 AI VCL -8/15* △ P HESS I - 7/1 ○ D/S ProSEDS 8/00*	*S / T-IV* IMEX - 3Q/01* GALEX - 9/15△ P UL SCISAT/TBD - 12/01	△ SC SMEX-8 - 7/02 P* SOLSTICE/TSIM-7/02 △ SH STEREO 1 - 9/02 SH△ STEREO 2 - 11/02 LC △ LC UNEX-3 2Q/02 UNEX-4 4Q/02	SH PICASSO/CENA -2/03 SH ESSP-4 - 3/03 SC EO 3 - 5/03 SMEX-9 - 10/03△TBD △ SC SPACETECH 5 - 9/03 LC△ LC UNEX-5 2Q/03 UNEX-6 4Q/03	SC SH SMEX-10 - 7/04 ALT-RADAR II 3/04 SH ESSP-5 - 3/04 SH EOS 4 6/04 EOS 5 - 9/04 SH LC△ LC UNEX -7 2Q/04 UNEX -8 4Q/04	△ SPACE TECH 6 2/05 SC EOS 6 7/05 SC SC SMEX-11 - 7/05 SC SH EO 4 -6/05 ESSP-6 - 1/05 LC△ LC UNEX -9 2Q/05 UNEX -10 4Q/05	SC ESSP-7 - 1/06 SH△ SPACETECH 7 - 9/06
•MED-LITE (ML) • DELTA 7325/7320 (D3) • DELTA 7425/7426 (D4)	△ D4 MARS LANDER 1 DEEP SPACE 2 1/3 △ D4 STARDUST - 2/7 △ D3 FUSE - 5/20 D3 EO1/SAC-C MU/CE - 12/15	D4△ MAP - 11/7 D3 IMAGE 2/15	D3 △ GENESIS - 1/07 △ D4 MARS LANDER 2- 4/10 ICESAT/ D3 CATSAT 7/01 D3 NOAA N 9/01*	D4 △ SPACETECH 3 6/02 D4 △ CONTOUR - NET 6/26 ML△ DISCOVERY 7 12/02	D3 NOAA-N' 12/03* (NET 9/02) △ ML MIDEX 3 - 6/03 ML△ DISCOVERY 8 12/03	△ ML MIDEX-4 - 6/04 ML△ DISCOVERY 9 12/04	△ ML MIDEX-5 - 6/05 ML△ DISCOVERY 10 12/05	△ ML MIDEX-6 - 6/06 ML△ DISCOVERY 11 12/06
•MEDIUM CLASS (MC) • DELTA 7920/7925 (D) • DELTA 7920 H (DH) • TITAN II (T-II) - VAFB	T-II QUIKSCAT 5/16 D LANDSAT 7 - 4/15 T-II NOAA-L - 12/99*	D TIMED/ JASON1 5/18 D GPB - 10/26 D EOS-PM - 12/21	D MARS ORBITER 2 3/30 T-II* NOAA-M 5/01* D △ SIRTF - 12/01	MC EOS-CHEM 12/02	△ MC SPACETECH 4 4/03		△ MC GLAST - 6/05 ML△ STP-3 - 10/05	
•INTERMEDIATE CLASS • ATLAS IIA (IIA) • ATLAS IIAS (IIAS) • DELTA III (DIII)	IIAS TERRA (EOS-AM1) 7/28 IIA □ GOES-L - 5/15 ○ IIA TDRS H - 9/30		IIA □ GOES-M- 7/01 DIII*□ GOES-N - 10/01* IIA ○ TDRS I - 12/01	○ IIA TDRS J - 6/02	□ DIII* GOES-O - 4/03 △ MARS SURVEYOR 6/03		△ SIM - 7/05	
•STS / IUS	△ I CHANDRA/AXAF 7/9				I* △ EUROPA ORBITER 10/03*			

* FOR NASA PLANNING PURPOSES

△ = OSS
□ = OES
○ = OSF
✓ = VAFB LAUNCH

K. PONIATOWSKI
C.SALVAS MANI-11-USPP FPB 3/3/99
Rev 3 3/18/99

ELV REQUIREMENTS
HOW TO GET A NASA LAUNCH SERVICE FOR A SECONDARY SPACECRAFT

- MISSION FROM SCIENTIFIC OR EDUCATIONAL ORG (US OR INTERNATIONAL COOPERATIVE)

- CONTACT THE KSC ELV PROGRAM OFFICE
- FILL OUT SECONDARY PAYLOAD QUESTIONAIRE (USERS GUIDE)
- KSC TO DETERMINE WHAT NASA MISSIONS HAVE EXCESS MARGIN
  - (OR USAF GPS MISSIONS)
- SPACECRAFT AND ORBIT COMPATIBLE
- FIND AN ENTERPRISE SPONSOR:
  - SPACE FLIGHT
  - AERO-SPACE TECHNOLOGY
  - EARTH SCIENCE
  - SPACE SCIENCE

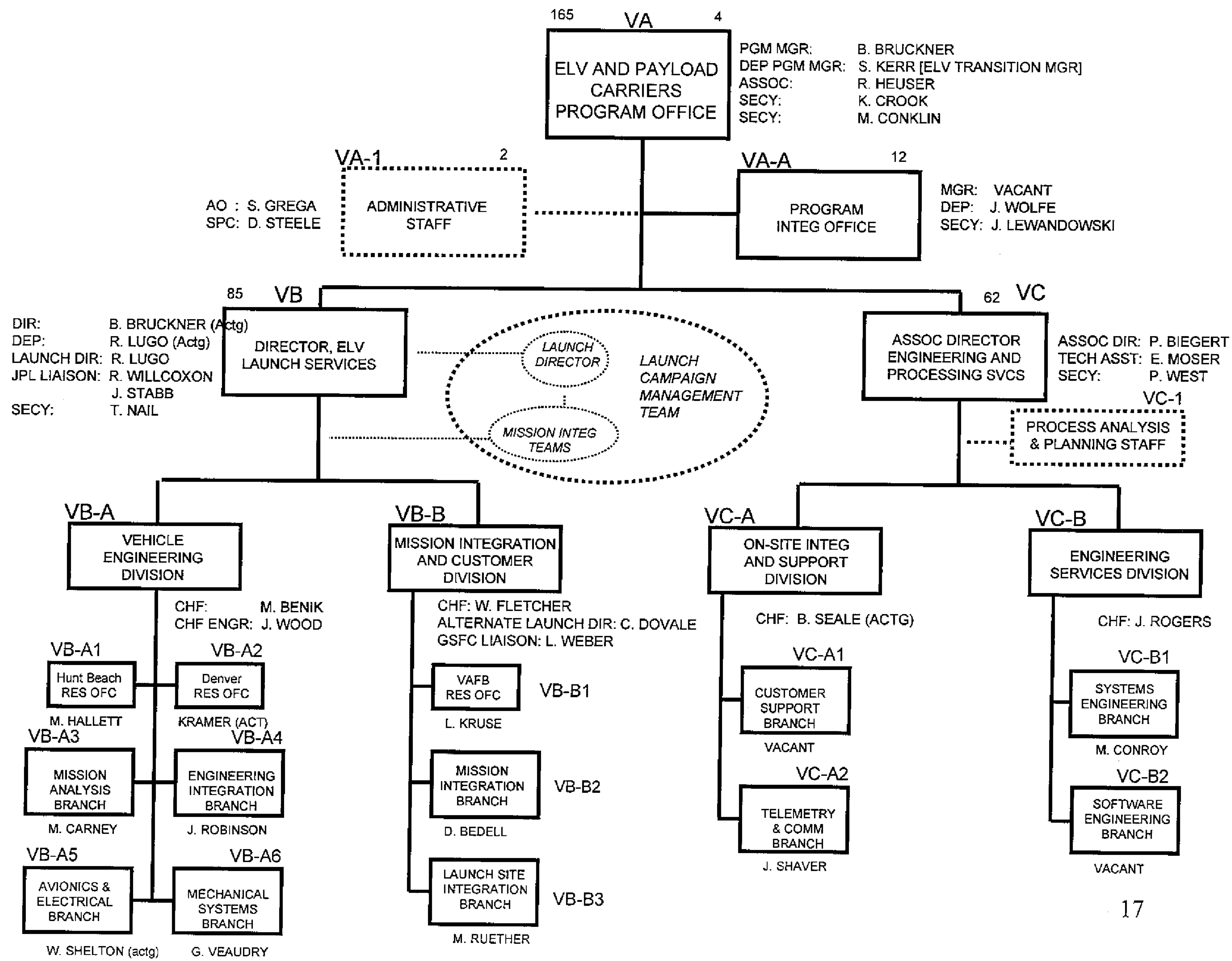
- APPROVED AT THE FLIGHT PLANNING BOARD

NASA ELV LONG RANGE PLANNING
POTENTIAL MISSION (CY 2006 - 2015)

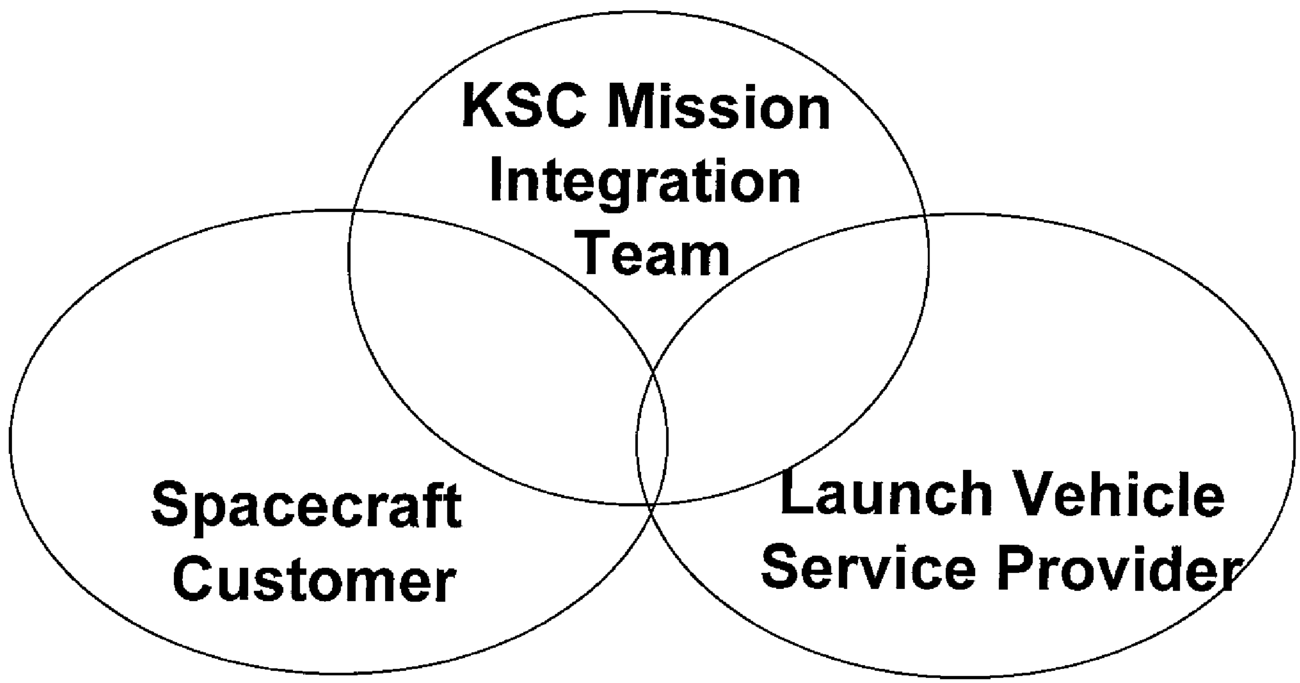
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
LOW-COST BOOSTER	UNESS	(one every year) (start '03)								
	UNEX	(two every year)								
SMALL CLASS	SMEX	(one every year)								
		NMP/EO	(one every odd year)							
	ESSP		ESSP		ESSP		ESSP		ESSP	
MEDIUM LITE CLASS		ESSP		ESSP		ESSP		ESSP		ESSP
		ALT-L2		ALT-R3						
		MIDEX	(one every year)							
		EOS	(one every year)							
		DISCOVERY	(one every year)							
MEDIUM CLASS		STP								
INTERMEDIATE CLASS	GOES	NGST MSR LANDER SOLAR PROBE	GOES	MSR ORBITER MSR LANDER						

WEST COAST LAUNCHES

K. PONIATOWSKI
C. SALVAS MANI-12 LRPPM 3/3/99
REV 1 3/18/99

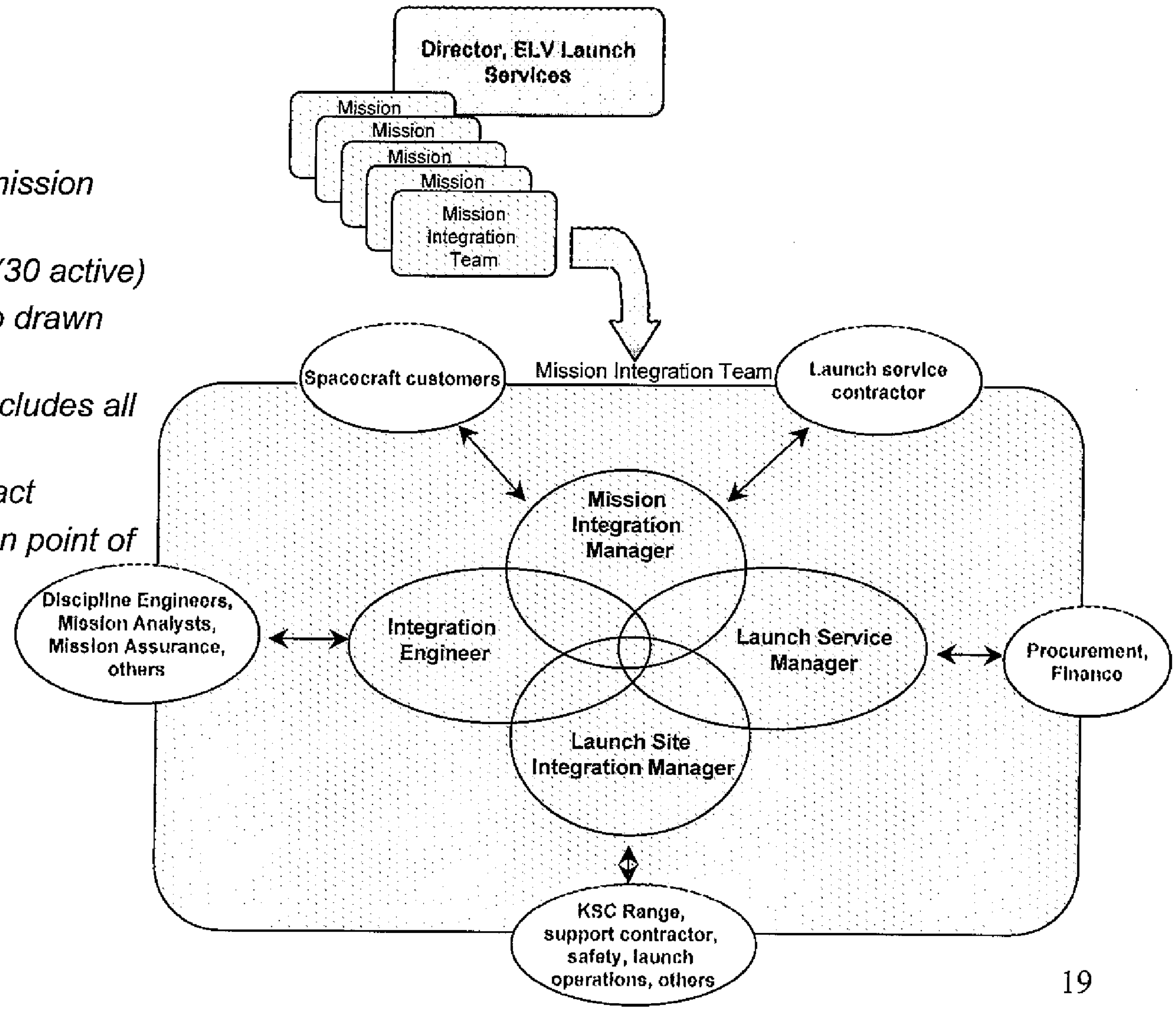

165
VA
4
ELV AND PAYLOAD CARRIERS PROGRAM OFFICE
PGM MGR: B. BRUCKNER
DEP PGM MGR: S. KERR [ELV TRANSITION MGR]
ASSOC: R. HEUSER
SECY: K. CROOK
SECY: M. CONKLIN
VA-1
2
ADMINISTRATIVE STAFF
AO : S. GREGA
SPC: D. STEELE
VA-A
12
PROGRAM INTEG OFFICE
MGR: VACANT
DEP: J. WOLFE
SECY: J. LEWANDOWSKI
85
VB
DIRECTOR, ELV LAUNCH SERVICES
DIR: B. BRUCKNER (Actg)
DEP: R. LUGO (Actg)
LAUNCH DIR: R. LUGO
JPL LIAISON: R. WILLCOXON
J. STABB
SECY: T. NAIL
LAUNCH DIRECTOR
MISSION INTEG TEAMS
LAUNCH CAMPAIGN MANAGEMENT TEAM
62
VC
ASSOC DIRECTOR ENGINEERING AND PROCESSING SVCS
ASSOC DIR: P. BIEGERT
TECH ASST: E. MOSER
SECY: P. WEST
VC-1
PROCESS ANALYSIS & PLANNING STAFF
VB-A
VEHICLE ENGINEERING DIVISION
CHF: M. BENIK
CHF ENGR: J. WOOD
VB-A1
Hunt Beach RES OFC
M. HALLETT
VB-A2
Denver RES OFC
KRAMER (ACT)
VB-A3
MISSION ANALYSIS BRANCH
M. CARNEY
VB-A4
ENGINEERING INTEGRATION BRANCH
J. ROBINSON
VB-A5
AVIONICS & ELECTRICAL BRANCH
W. SHELTON (actg)
VB-A6
MECHANICAL SYSTEMS BRANCH
G. VEAUDRY
VB-B
MISSION INTEGRATION AND CUSTOMER DIVISION
CHF: W. FLETCHER
ALTERNATE LAUNCH DIR: C. DOVALE
GSFC LIAISON: L. WEBER
VAFB RES OFC
VB-B1
L. KRUSE
MISSION INTEGRATION BRANCH
VB-B2
D. BEDELL
LAUNCH SITE INTEGRATION BRANCH
VB-B3
M. RUETHER
VC-A
ON-SITE INTEG AND SUPPORT DIVISION
CHF: B. SEALE (ACTG)
VC-A1
CUSTOMER SUPPORT BRANCH
VACANT
VC-A2
TELEMETRY & COMM BRANCH
J. SHAVER
VC-B
ENGINEERING SERVICES DIVISION
CHF: J. ROGERS
VC-B1
SYSTEMS ENGINEERING BRANCH
M. CONROY
VC-B2
SOFTWARE ENGINEERING BRANCH
VACANT

Mission Integration Philosophy



Mission Integration Teams

- *Features:*
- *Total management of mission integration process*
- *One team per mission (30 active)*
- *Core team membership drawn from ELV Program*
- *Expanded core team includes all other support functions*
- *Customer point of contact*
- *Launch services mission point of contact*



Extended MIT Members

MIM - Team Lead
- GSFC and JPL
  - Resident Offices
- Launch Service Provider
- Spacecraft Launch Vehicle Integrator

LSIM:
- Range Safety
- VAFB Resident Office
- KSC Communications
- KSC, Range, Contractor Support Orgs

Integration Engineer:
- Mission Analysts
- Discipline Engineers
- Huntington Beach and Denver Resident Offices

LSM:
- Business Management
- Finance
- Procurement

MIM Responsibilities

Primary Customer Interface for Mission Specific Integration

- Chair and Manage (KSC) Mission Integration Team (MIT)
- Overall Mission Management (technical, contract deliverables, budget, schedule, etc.)
- Co-Chair Overall Integration Working Group Meetings with Launch Service Provider
- Responsible for Mission Unique Approval & Budget
- Contracting Officer Technical Representative (COTR) for Mission Unique
- Approval of the contractual deliverables after coordination and review by MIT

Integration Engineer Responsibilities

Coordinates and Leads KSC Engineering Effort

- Responsible for Technical Content of Mission Specific & Other Docs
- Leads Resolution of Technical Issues on the Program
- Establishes Engineering Priorities,coordinated with MIM
- Identifies Issues to Engineering Management that Require Engineering Review Board (ERB)
- Maintains Awareness of Vehicle History for Vehicle assigned to Mission
- Works with Resident Office to organize and accomplish hardware/software reviews

Launch Service Manager (LSM) Responsibilities

Provides Program & Business Management for Launch Services Contracts

- Assesses and works Programmatic impacts and changes across the fleet
- COTR and Primary Interface to Contractor for core vehicle
- Authorizes, reviews and provides business assessment of early mission studies, task orders, change orders, and mission unique
- Financial Management
  - Budget Development and Execution

Launch Site Integration Manager Responsibilities

- **Provides planning and coordinates support for all aspects of payload customer stand alone activities at the launch site** (e.g., facilities, schedules, safety, budget, networks, communication, etc.)
  - Chairs Ground Operation Working Group Meetings
  - Develops the Launch Site Support Plan
- **Assures payload customer requirements and schedules for integrated launch site activities are coordinated with the launch vehicle** (e.g., PRD inputs, countdown schedules, procedure inputs)
- **Serves as the NASA point-of-contact for launch vehicle activities at the launch site** (e.g., integrated procedure review, range support, schedules, reviews, etc.)
- **Coordinates Launch Management activities**
  - Management Reviews, seating charts, dress rehearsals
  - Supports NASA Launch Manager

Working Relationships (cont.)

- **LSIM Functions**
  - Combines the old LSSM and LOM functions that NASA used to have
  - Provides one interface at the Launch Site to do payload and launch vehicle integration, scheduling and ops planning
- **Boeing - PGOC Support Services Contract**
  - Support to MIT
  - Technology support to Engineering
- **Engineering Interfaces**
  - Integration Engineer functions as technical lead
  - Individual engineering disciplines interface with their counterparts at the Launch Service Provider and Spacecraft Project

Dual Ride Options

- Existing UELV, SELVS-KSC, and Med Lite Contracts have provisions for Dual Rides (Co-manifested)
- Dual Payload Attach Fittings also available to fly secondary payloads
- Ordering period is 18 to 30 months depending on contract
- Mass capability from approximately 150 kg to 1300 kg
- Volume capability from approximately 26” Dia x 22” to 95” Dia x 70”
- Pegasus-XL, Standard Taurus and Delta 732x/742x vehicles available
  - MELVS contract for Delta 792X is “sold out”
  - Larger vehicles TBD under NLS procurement which is currently active

Pegasus-XL Dual Payload Attach Fitting

EXPENDABLE LAUNCH VEHICLES

Payload mass typically limited by orbit requirements, not by structural capability

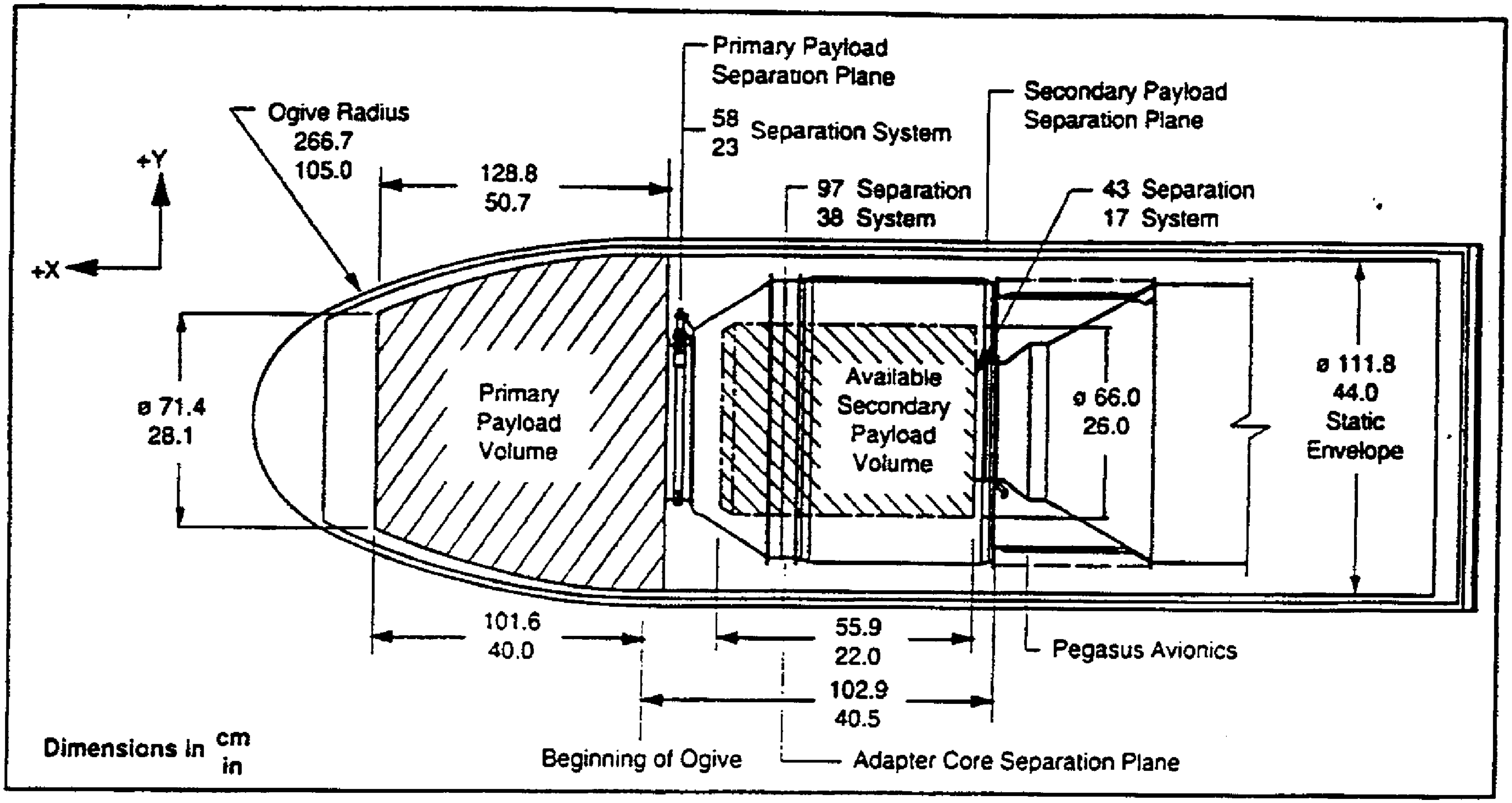


Figure D-6. *Dual Payload Attach Fitting (DPAF) Configuration.*

Pegasus-XL Dual Ride

Payload mass typically limited by orbit requirements, not by structural capability

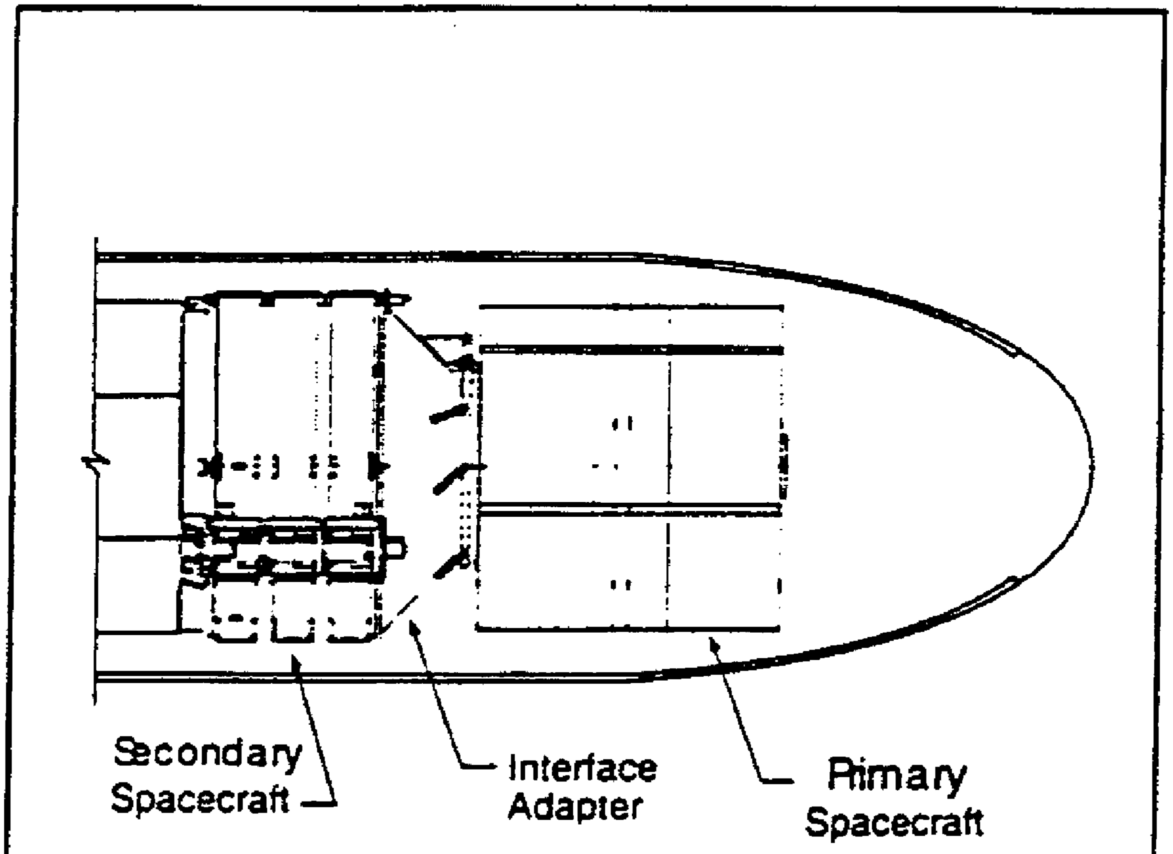


Figure D-7. *Load Bearing Secondary Configuration*

TAURUS Dual Payload Attach Fittings

EXPENDABLE LAUNCH VEHICLES

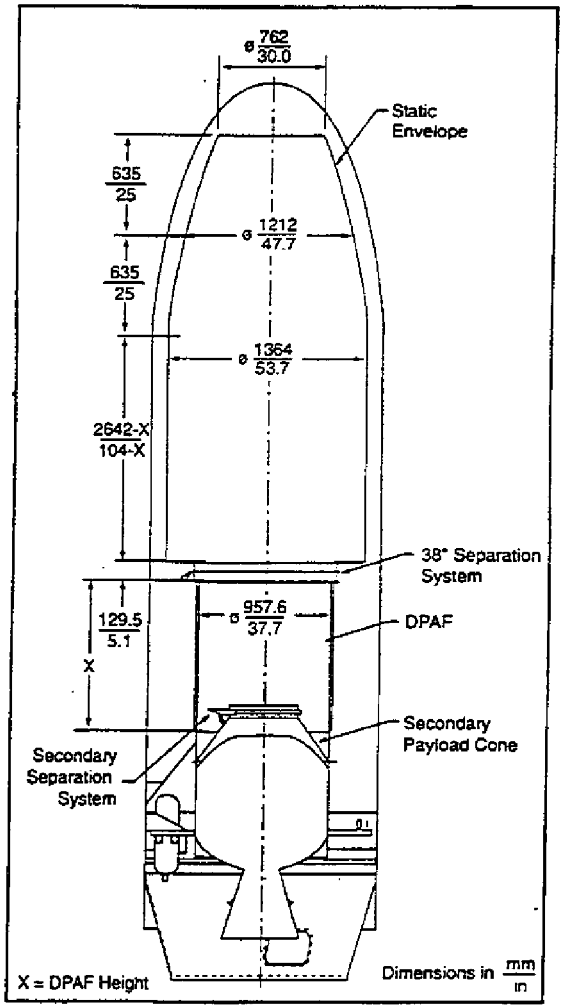


Figure 4.3.1-1: *Taurus 38" DPAF*

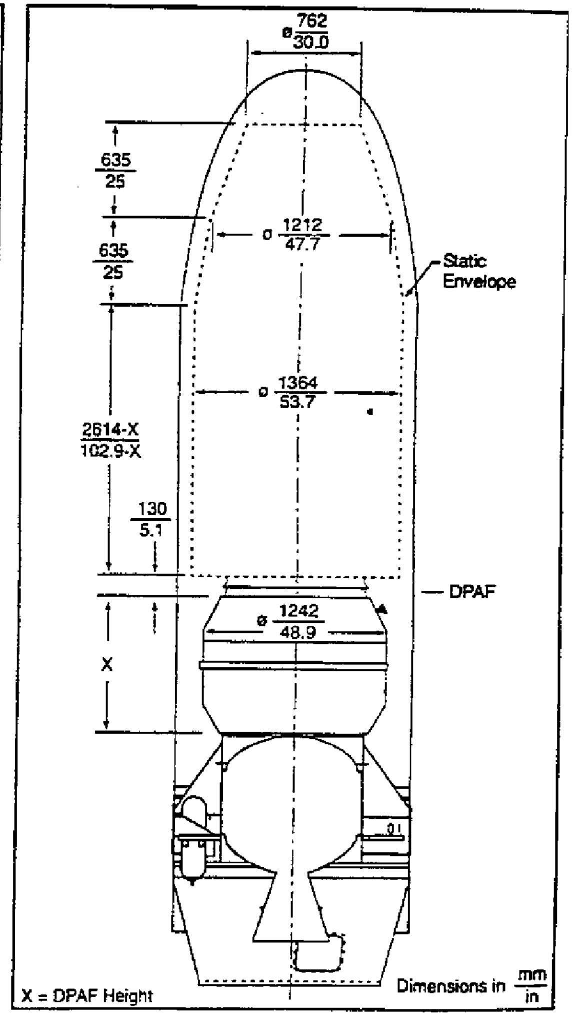


Figure 4.3.2-1: *Taurus 50" DPAF*

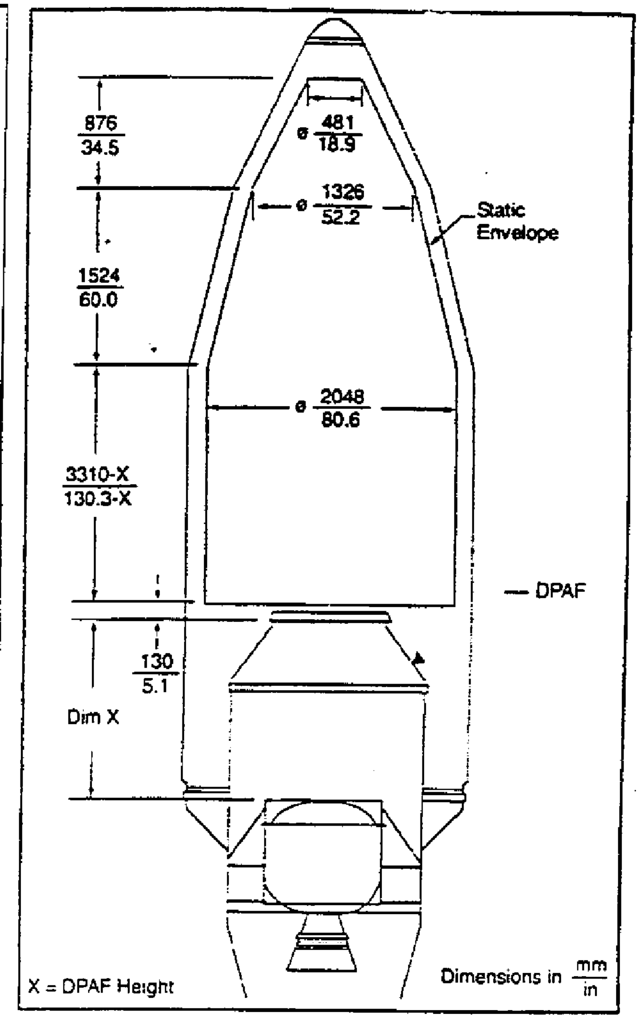
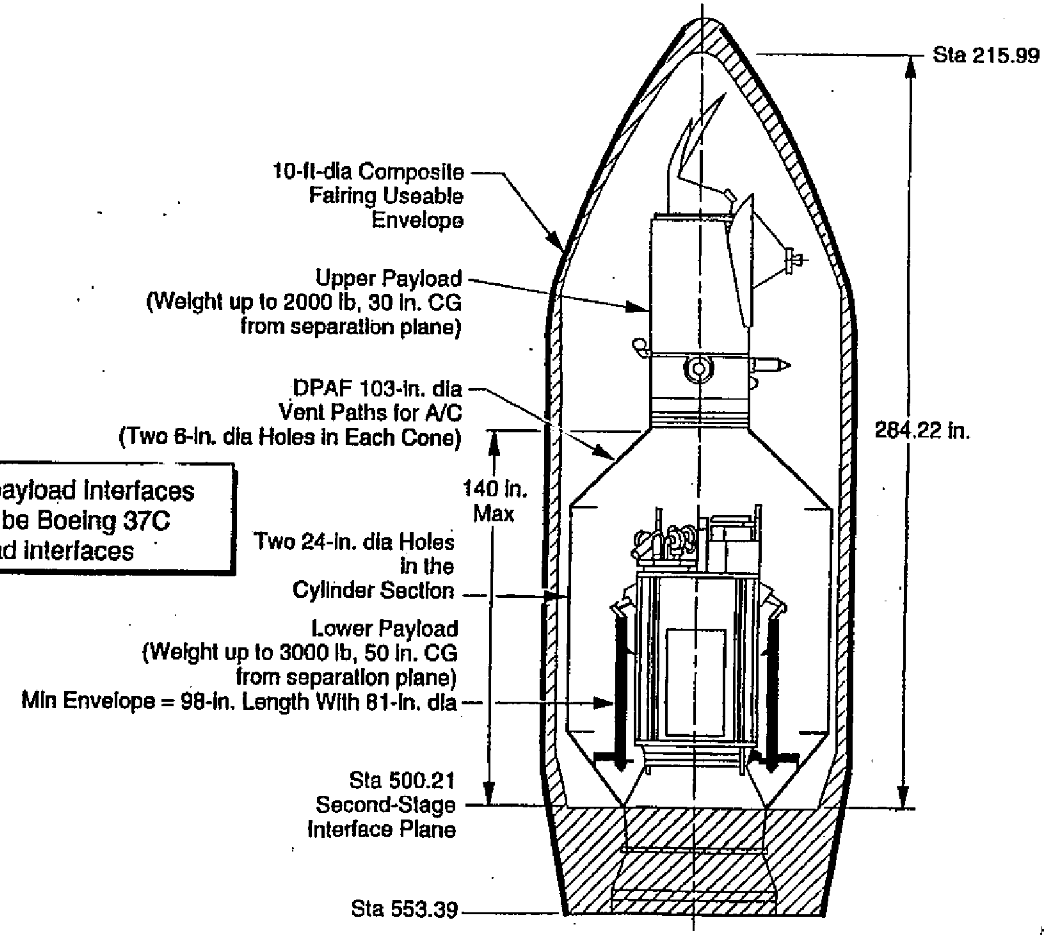


Figure 4.3.3-1 *Taurus 63" DPAF*

DUAL PAYLOAD ATTACH FITTING (DPAF)



Both payload interfaces would be Boeing 37C payload interfaces

Secondary Payload Options

- Secondary Payload (SP) Requirements
  - SP shall present no hazard (ordnance, radiation, contamination etc) to the primary payload
  - Acceptance of the SP is subject to approval of the primary payload program manager
  - Primary payload orbit requirements and launch date shall not be affected by SPs
  - Approval of SPs will be considered only if sufficient performance margin exists for the primary mission. Approval could be withdrawn if the margin is unexpectedly reduced
- Existing UELV, SELVS-KSC, and Med Lite Contracts have SP provisions
- Ordering period is 18 to 24 months depending on mission
- Mass capability up to approximately 100 kg
- Volume capability from approximately 11.25" x 19" x 14" to 26" Dia x 22"

Delta Separating Secondary Payload Interface

(Spacecraft Supplied Adapter)

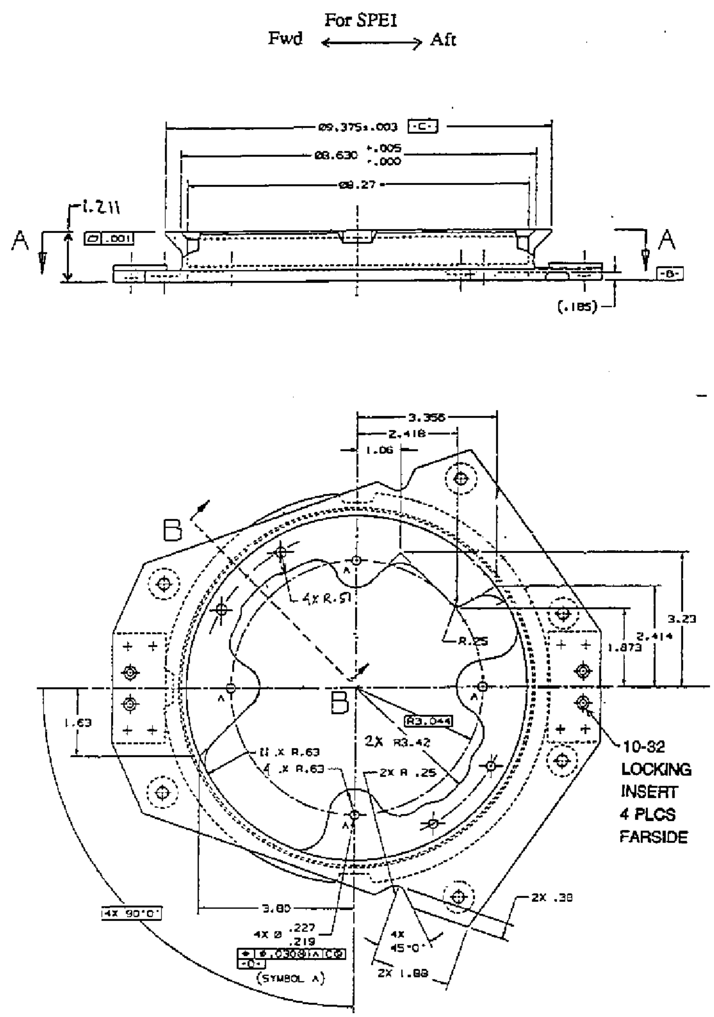
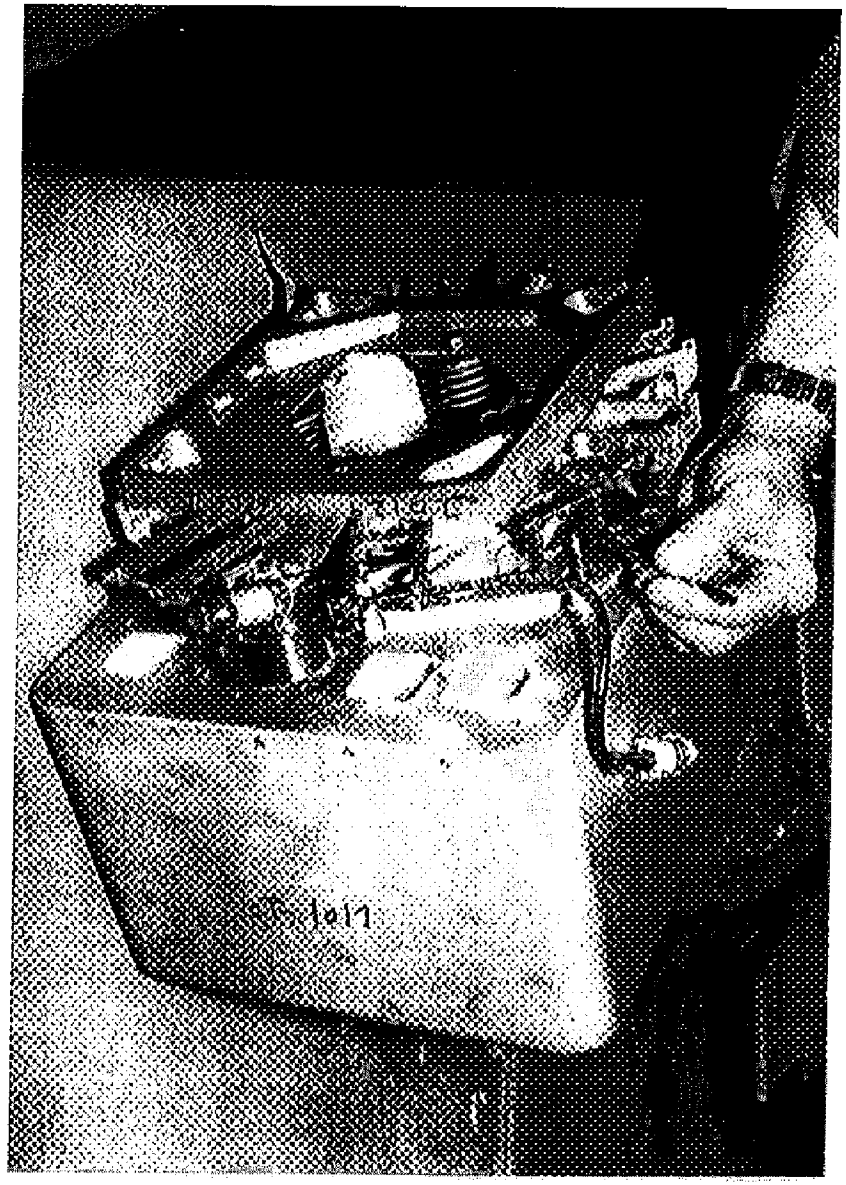


Figure 5.5a Example of Payload Adapter Assembly for Separating SPs

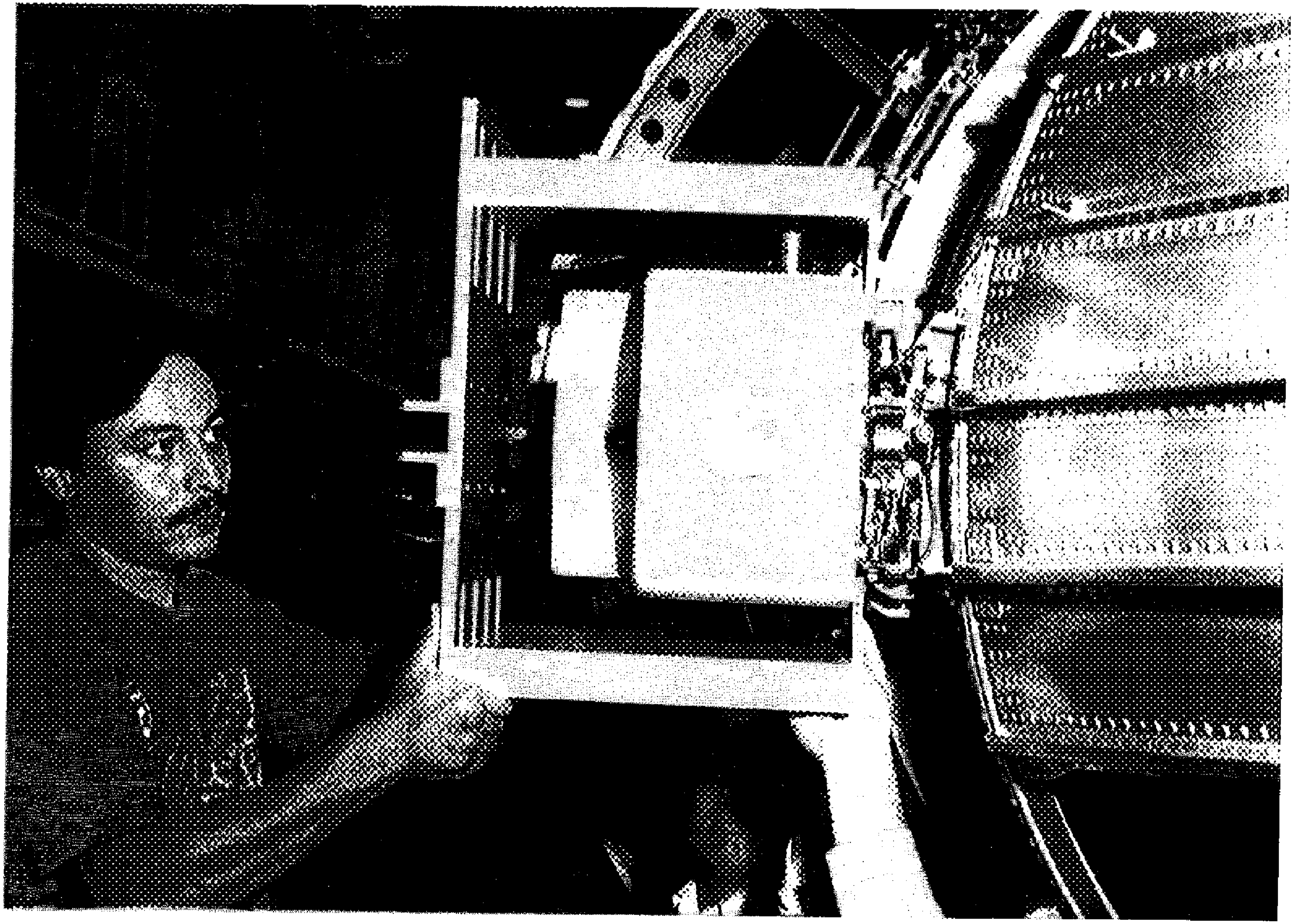
Payload Size Excluding Adapter
11.25" x 19" x 14"
or 10.25" x 19" x 24"
Payload Mass: Including Adapter
45 kg @ 5.0 inch C.G.

Delta Separating Secondary Payload with Adapter, Launch Vehicle PAF and Clampband

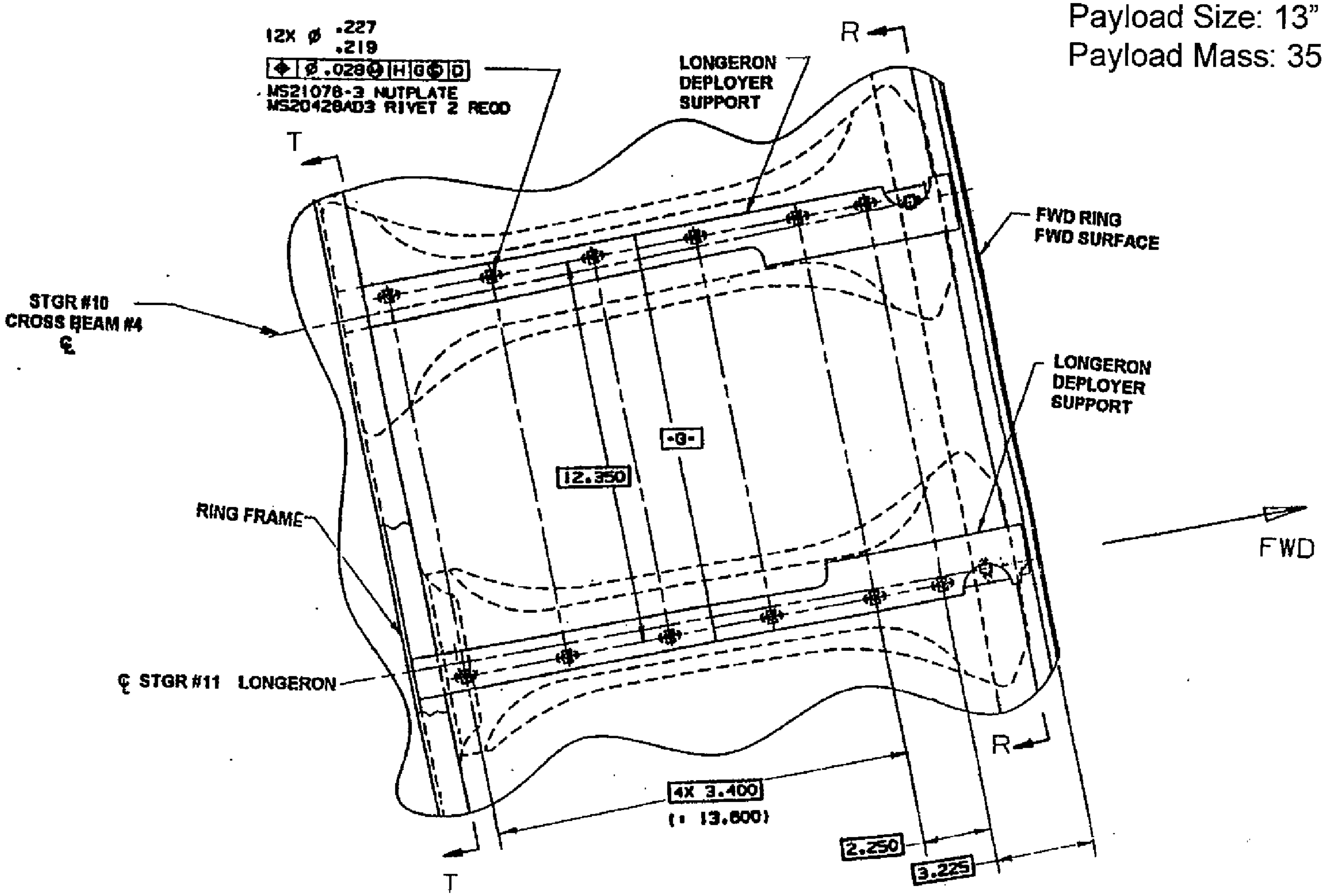
EXPENDABLE LAUNCH VEHICLES



Delta Separating Secondary Payload Attached to Second Stage with GSE



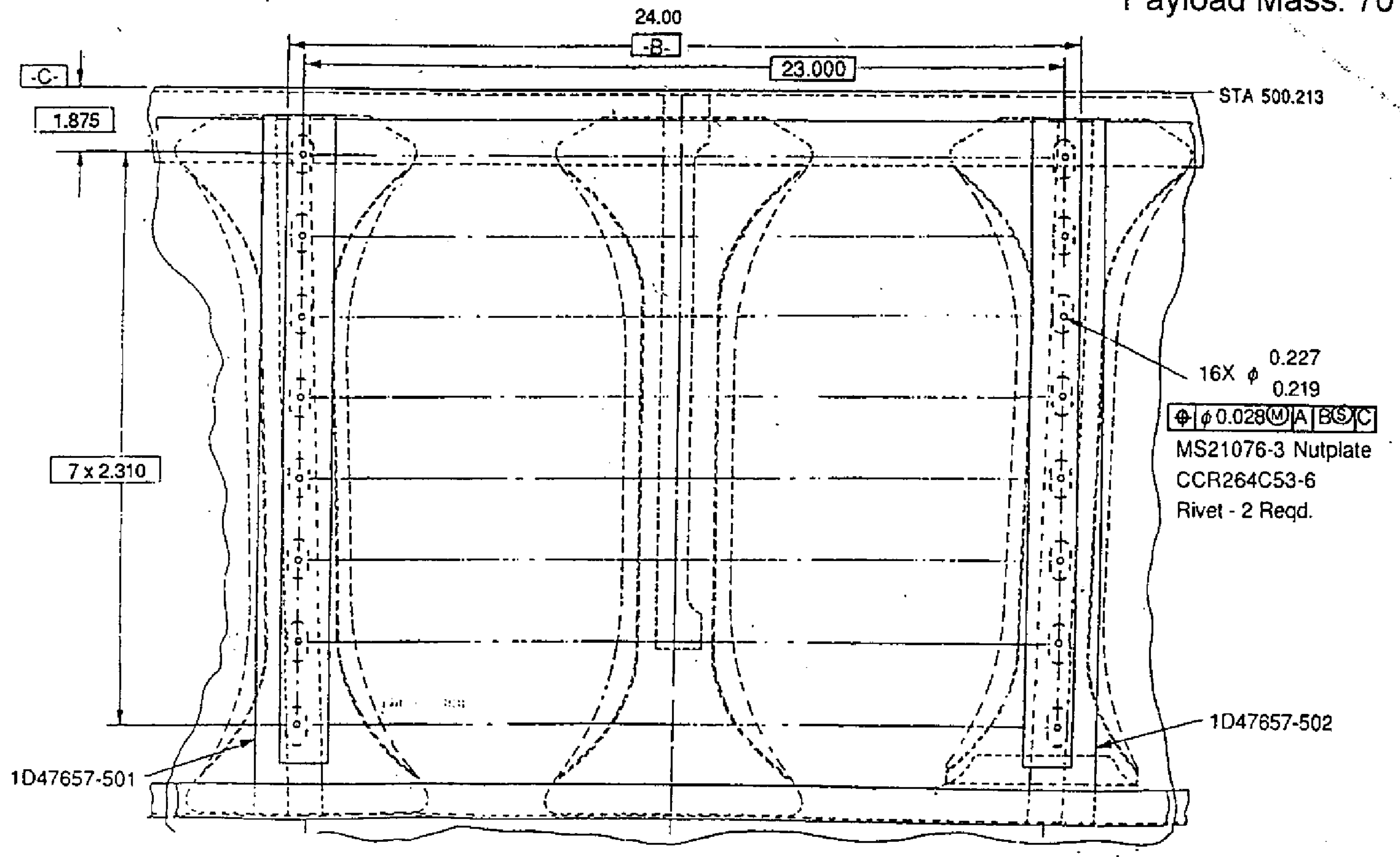
Delta Non Separating Secondary Interface



Payload Size: 13" x 19" x 14"
Payload Mass: 35 kg

Delta Non Separating Interface

Payload Size: 11" x 25" x 24"
Payload Mass: 70 kg



Note: Envelope width is 24.00 inches.

Recent/Current NASA Secondary Payloads

EXPENDABLE LAUNCH VEHICLES

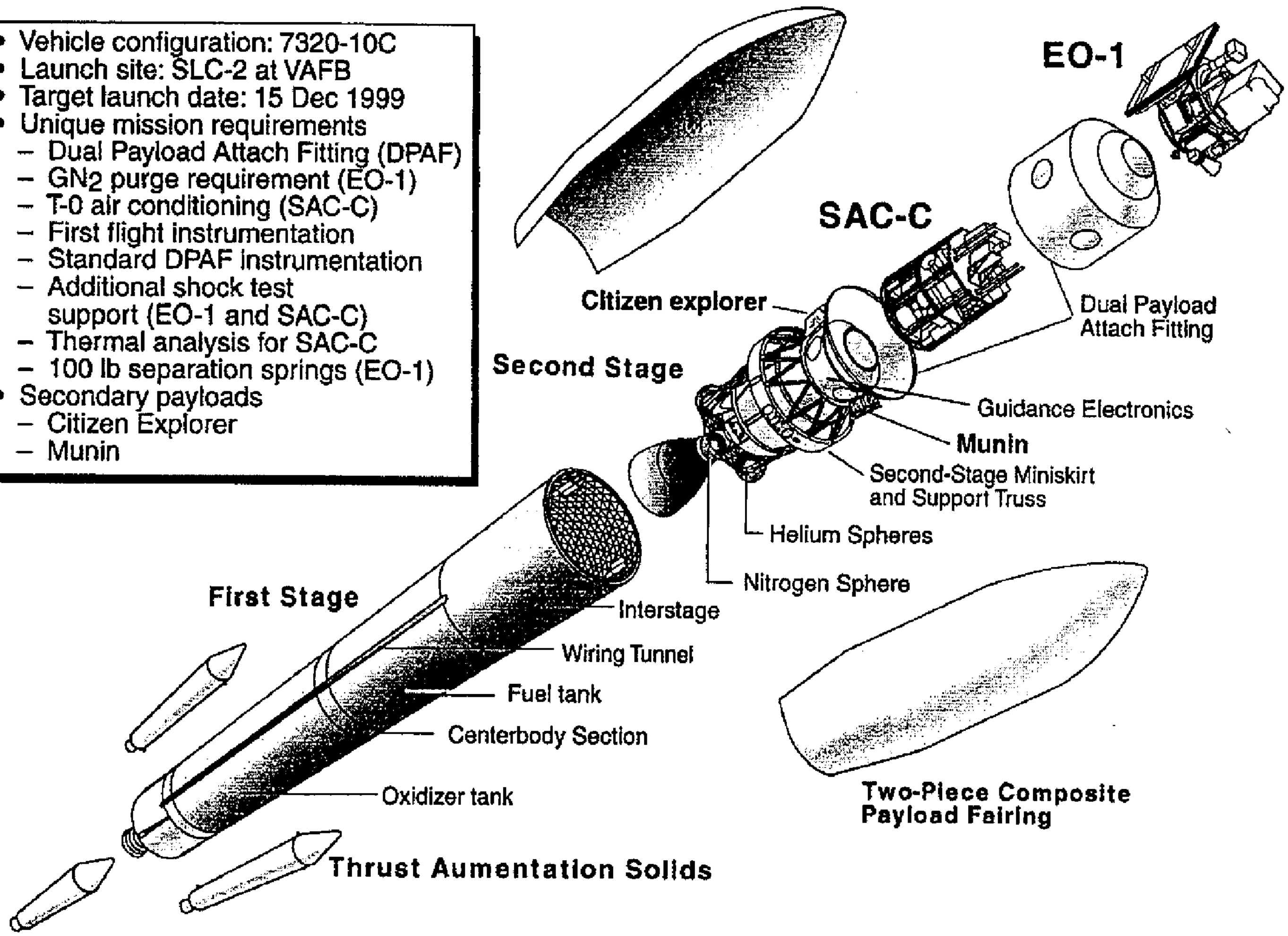
Mission	Mass	Date	Vehicle	Type
DUVE	102 kg	7/92	Delta	2 Non Separating
SEDS-1	45 kg	3/93	Delta	Tether
PMG	55 kg	6/93	Delta	Tether + Diagnostics
SEDS-2	50 kg	3/94	Delta	Tether
SURFSAT	35 kg	11/95	Delta	2 Non Separating
SEDSAT	40 kg	10/98	Delta	Separating
Orsted	65 kg	1/99	Delta	Separating
Sunsat	65 kg	1/99	Delta	Separating
ACRIM	120 kg	10/99	Taurus	DPAF
Citizen Explorer	45 kg	12/99	Delta	Separating
Munin	6 kg	12/99	Delta	Self Separating
ProSEDS	105 kg	8/00	Delta	Tether
CATSAT	135kg	7/02	Delta	DPAF

Example of Dual Mission and 2 Secondary Payloads

EXPENDABLE LAUNCH VEHICLES

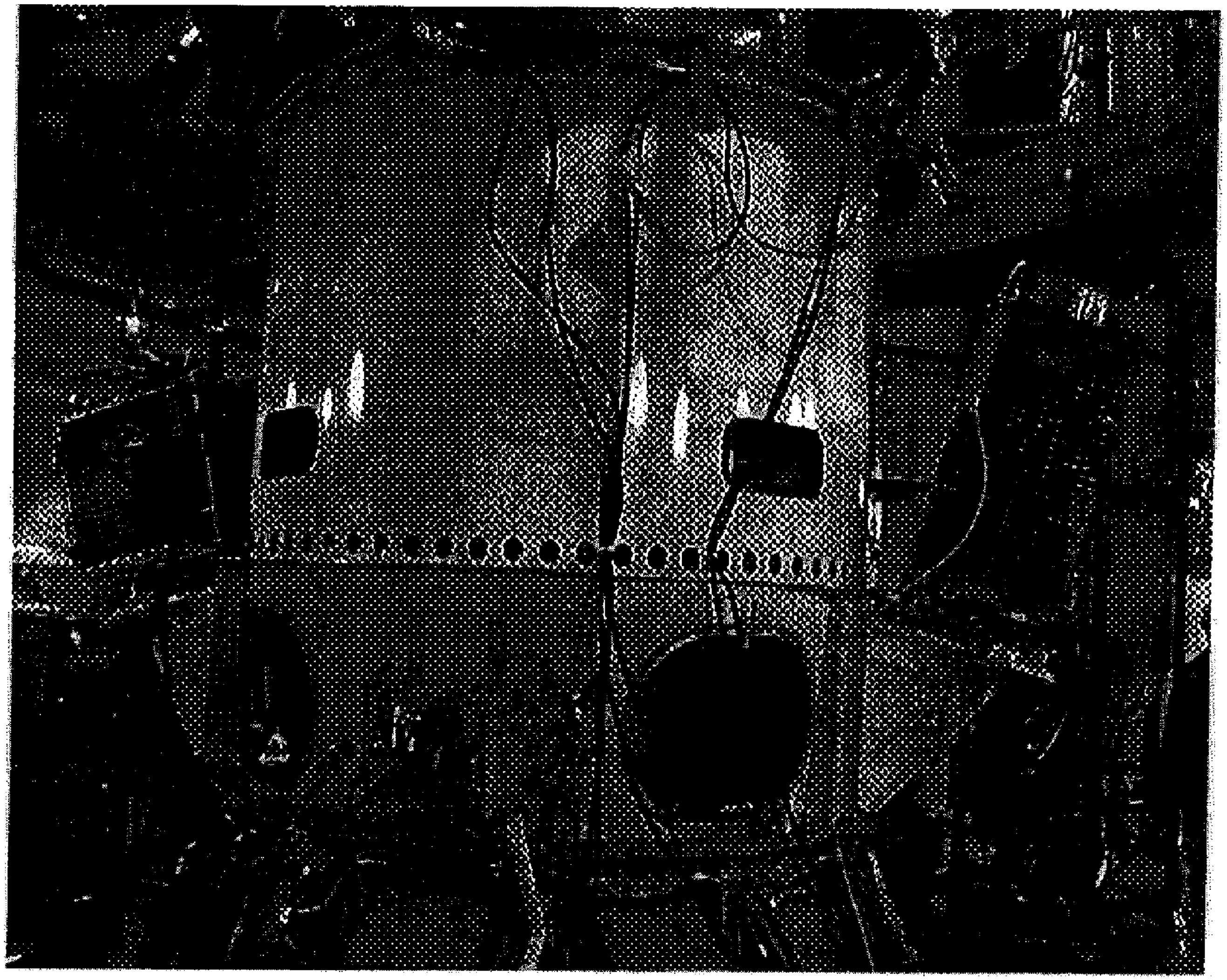
Launch Date 12/99

- Vehicle configuration: 7320-10C
- Launch site: SLC-2 at VAFB
- Target launch date: 15 Dec 1999
- Unique mission requirements
  - Dual Payload Attach Fitting (DPAF)
  - GN_2 purge requirement (EO-1)
  - T-0 air conditioning (SAC-C)
  - First flight instrumentation
  - Standard DPAF instrumentation
  - Additional shock test support (EO-1 and SAC-C)
  - Thermal analysis for SAC-C
  - 100 lb separation springs (EO-1)
- Secondary payloads
  - Citizen Explorer
  - Munin



Orsted and Sunsat Separating Secondary Payloads

Unique opportunity existed with USAF Argos Spacecraft which required spacers below PAF



Key ELV Contacts

Mission Integration and Customer Division Chief

Bill Fletcher		(407) 853-5761

Mission Integration Branch Chief

Darren Bedell		(407) 853-2166

Advance Mission Integration Managers

Frank Stone		(407) 476-3625
Tom Shaw		(407) 476-3640

Resident Liaison Offices

Laura Weber	GSFC	(301) 286-6922
Rita Willcoxon	JPL	(818) 354-4788
Johnathan Stabb	JPL	(818) 354-2489

Missions with Potential Availability for Dual Rides and/or Secondary Payloads

Mission	Date	Orbit	Mass Margin
EOS-PM Delta	12/00	700 km @ 98 deg	TBD Pending Trajectory Analysis
SCISAT Pegaus-XL	12/01	650 km @ 65 deg	1/2 Pegaus-XL less DPAF
GPS Delta	Various	187 km x 1189 km @ 37.2 deg	Separating SP 45 kg or Non Separating 70 kg Total margin 105 kg

Orbital Launch Systems

NRO Rideshare Conference

April 16, 1999

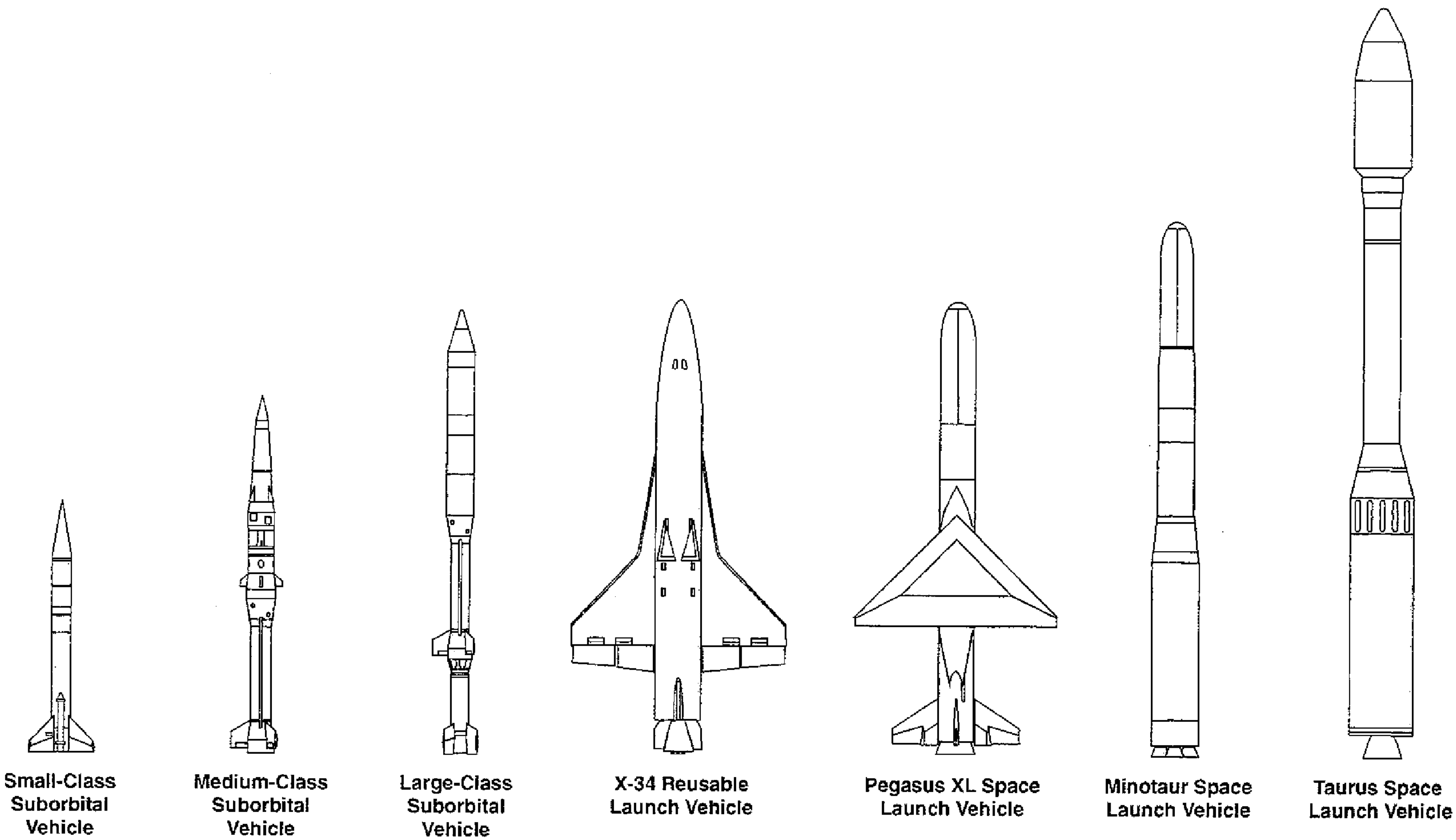
EDWARD MORRIS, JR.
Director, New Initiatives
Pegasus Program Office

Orbital Sciences Corp.
21700 Atlantic Blvd.
Dulles, VA 20166

Tel: 703-406-5223
Fax: 703-406-3412
E-mail: morris.ed@orbital.com

990409.01b

Orbital's Family of Launch Vehicles



980811.15

Pegasus and Taurus Flight Heritage (Cont'd)

Orbital

Integ & Test Launch Site		Customer	Mission	1996	1997	1998	1999
VAFB/WR	F10	USAF	REX-II	3/8 XL			
VAFB/WR	F11	BMDO	MSTI-3	5/16 Std			
VAFB/WR	F12	NASA	TOMS-EP	7/2 XL			
VAFB/WR	F13	NASA	FAST	8/21 XL			
VAFB/WFF	F14	NASA	SACB HETE	11/4 XL			
Spain/Spain	F15	INTA	MINISAT 01 Celestis		4/21 XL		
VAFB/WR	F16	ORBIMAGE	OrbView-2		8/1 XL		
VAFB/WR	F17	USAF DoE	FORTE		8/29 XL		
WFF/WFF	F18	USAF	STEP-M4		10/22 XL		
VAFB/WFF	F19	ORBCOMM	ORBCOMM-1 FM5-12		12/23 XL/HAPS		
VAFB/WR	T2	BATC ORBCOMM	GFO FM3 & FM4			2/10	
VAFB/WR	F20	NASA Orbital	SNOE BATSAT (T-1)			2/25 XL	
VAFB/WR	F21	NASA	TRACE			4/1 XL	
VAFB/WFF	F22	ORBCOMM	ORBCOMM-2 FM 13-20			8/2 XL/HAPS	
VAFB/WFF	F23	ORBCOMM	ORBCOMM-3 FM21-28			9/23 XL/HAPS	
VAFB/WR	T3	DoD	STEX			10/3	
VAFB/ER	F24	Brazil NASA	SCD-2 Wing Glove			10/22 Std	
VAFB/WR	F25	NASA	SWAS			12/6 XL	
VAFB/WR	F26	NASA	WIRE				3/4 XL

990326.01-2

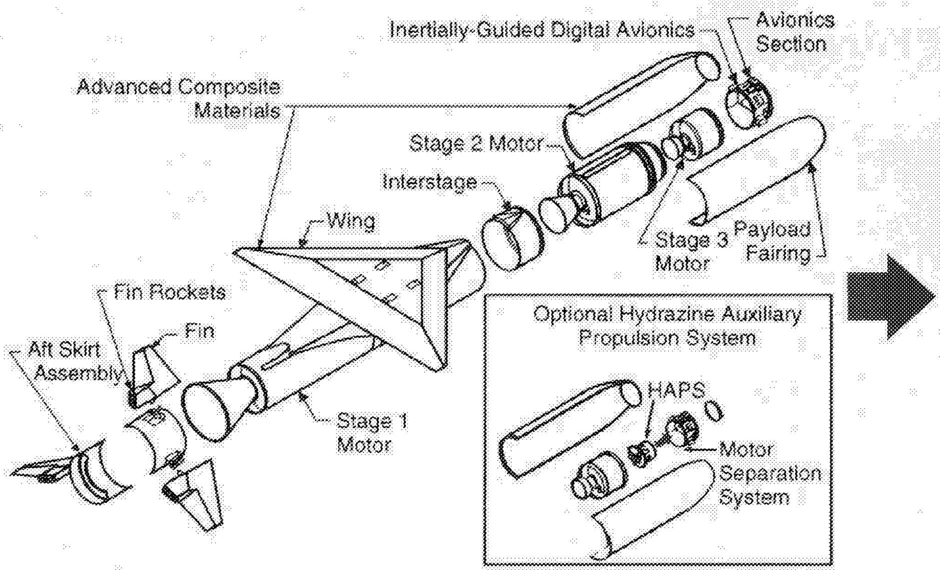
Pegasus and Taurus Flight Heritage

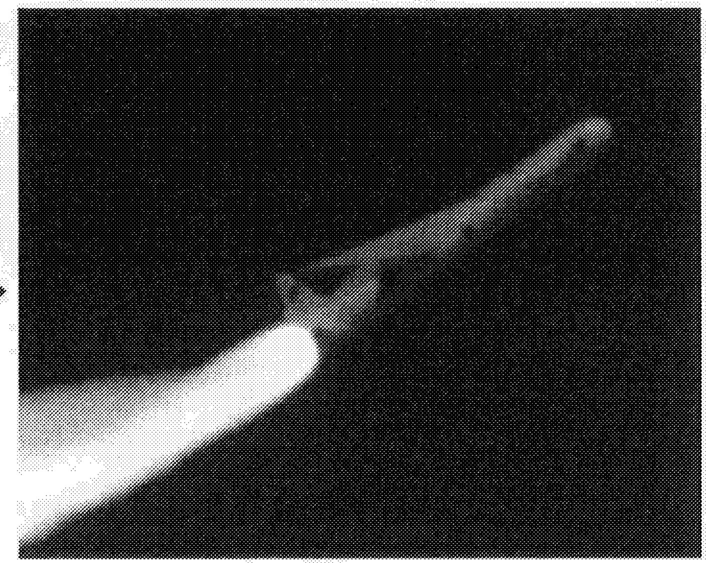
Integ & Test Launch Site	Customer	Mission	1990	1991	1993	1994	1995
DFRF/WR	F1 DoD NASA	Pegsat Navysat	4/5/90 Std				
DFRF/WR	F2 DoD	7 Microsats		7/17/91 Std/HAPS			
DFRF/ER	F3 Brazil Orbital	SCD-1 OXP-1			2/9 Std		
DFRF/WR	F4 USAF DoE Orbital	ALEXIS OXP-2			4/25 Std		
VAFB/WR	T1 DoD	STEP-M0 DARPASAT				3/13	
DFRF/WR	F5 USAF	STEP-M2				5/19 Std/HAPS	
VAFB/WR	F6 USAF	STEP-M1 FX-A				6/27 XL	
DFRF/WR	F7 USAF	APEX				8/3 Std	
VAFB/WR	F8 ORBCOMM ORBIMAGE	FM1 & FM2 OrbView-1					4/3 Std
VAFB/WR	F9 USAF	STEP-M3					6/22 XL

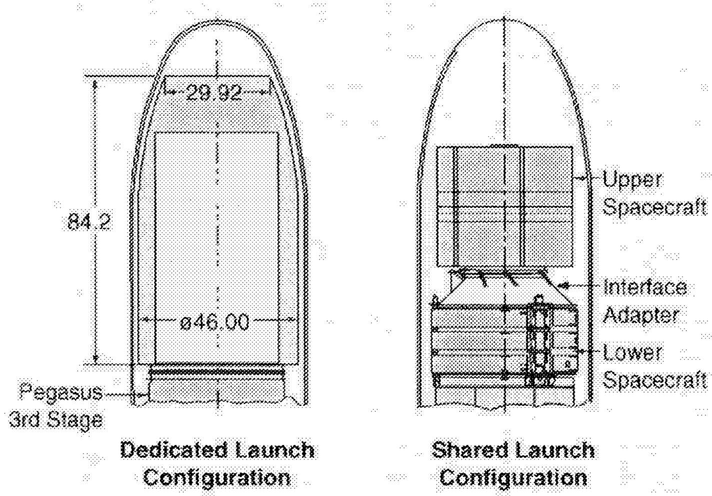
DFRF – Dryden Flight Research Facility
WR – Western Range
ER – Eastern Range
VAFB – Vandenberg AFB

990326.01-1

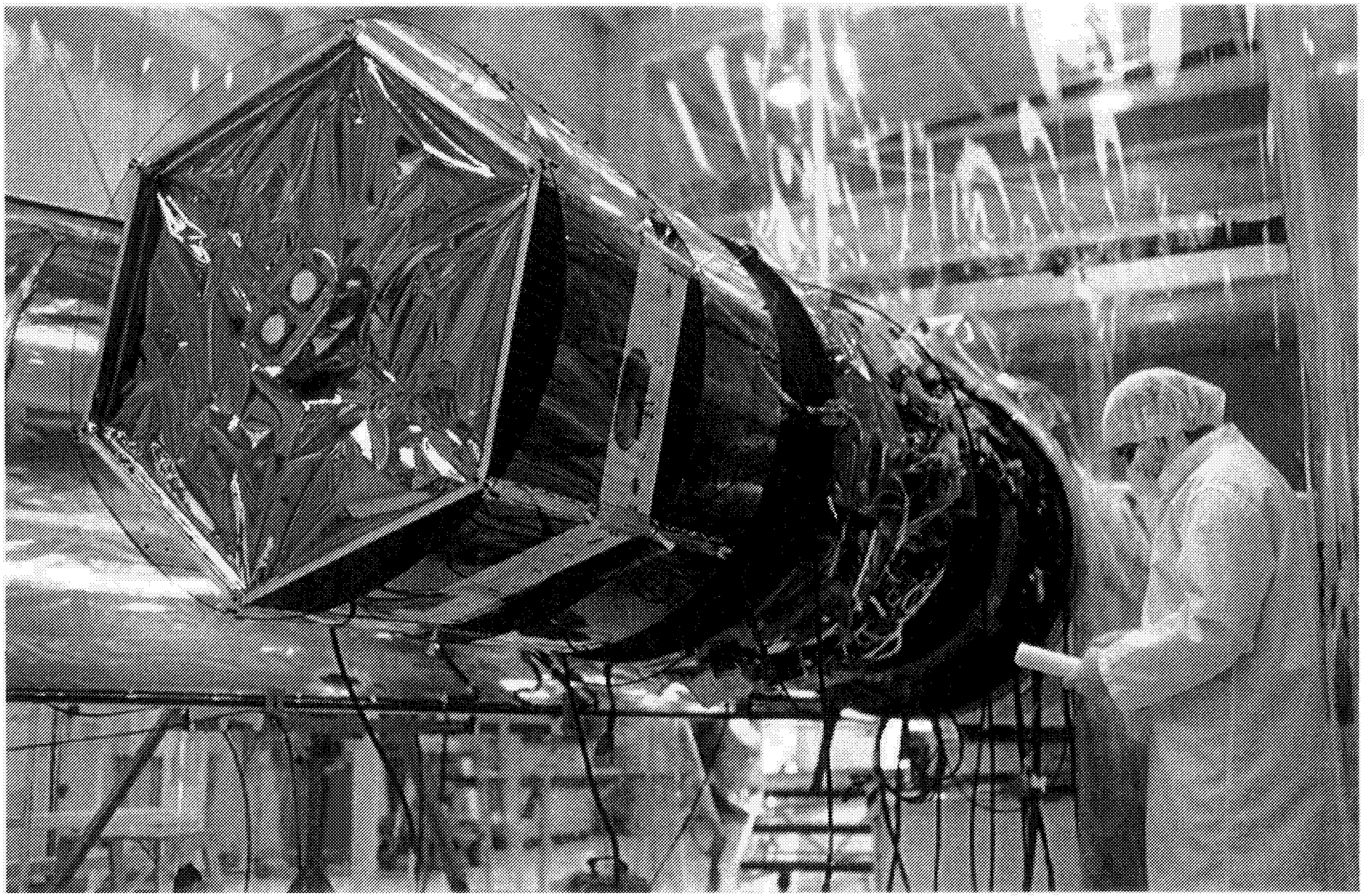
Pegasus Air Launch Vehicle



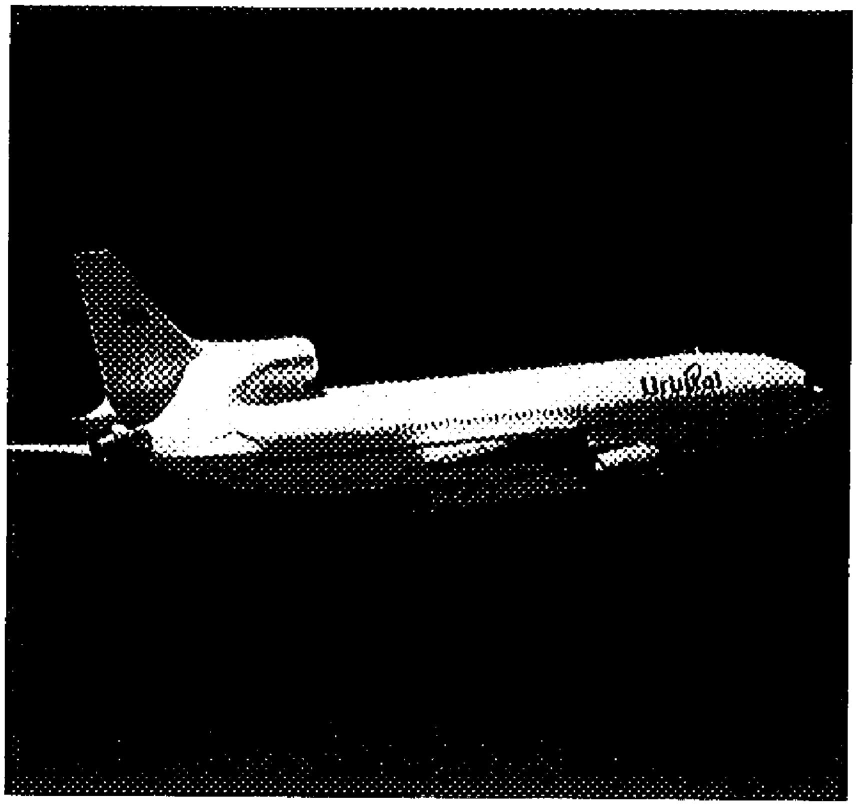


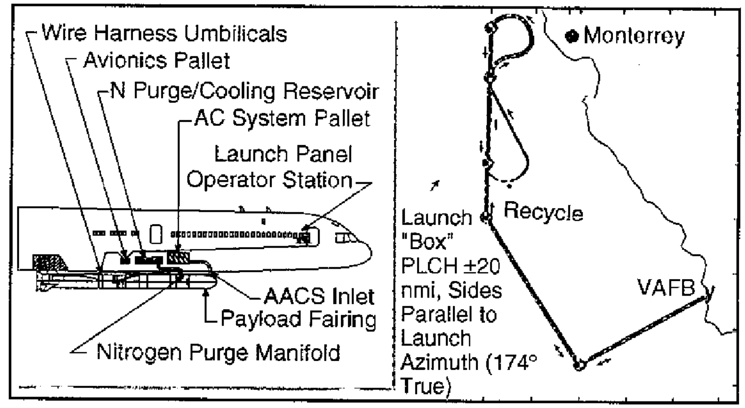


- Pegasus XL Is a Winged, 3-Stage Solid Rocket Booster
- Air Launched from L-1011 Carrier Aircraft
- System Mobility Optimizes Cost and Performance
- Commercially-Developed, Government-Certified
- Base of Operations at Vandenberg AFB, CA



L-1011 Carrier Aircraft



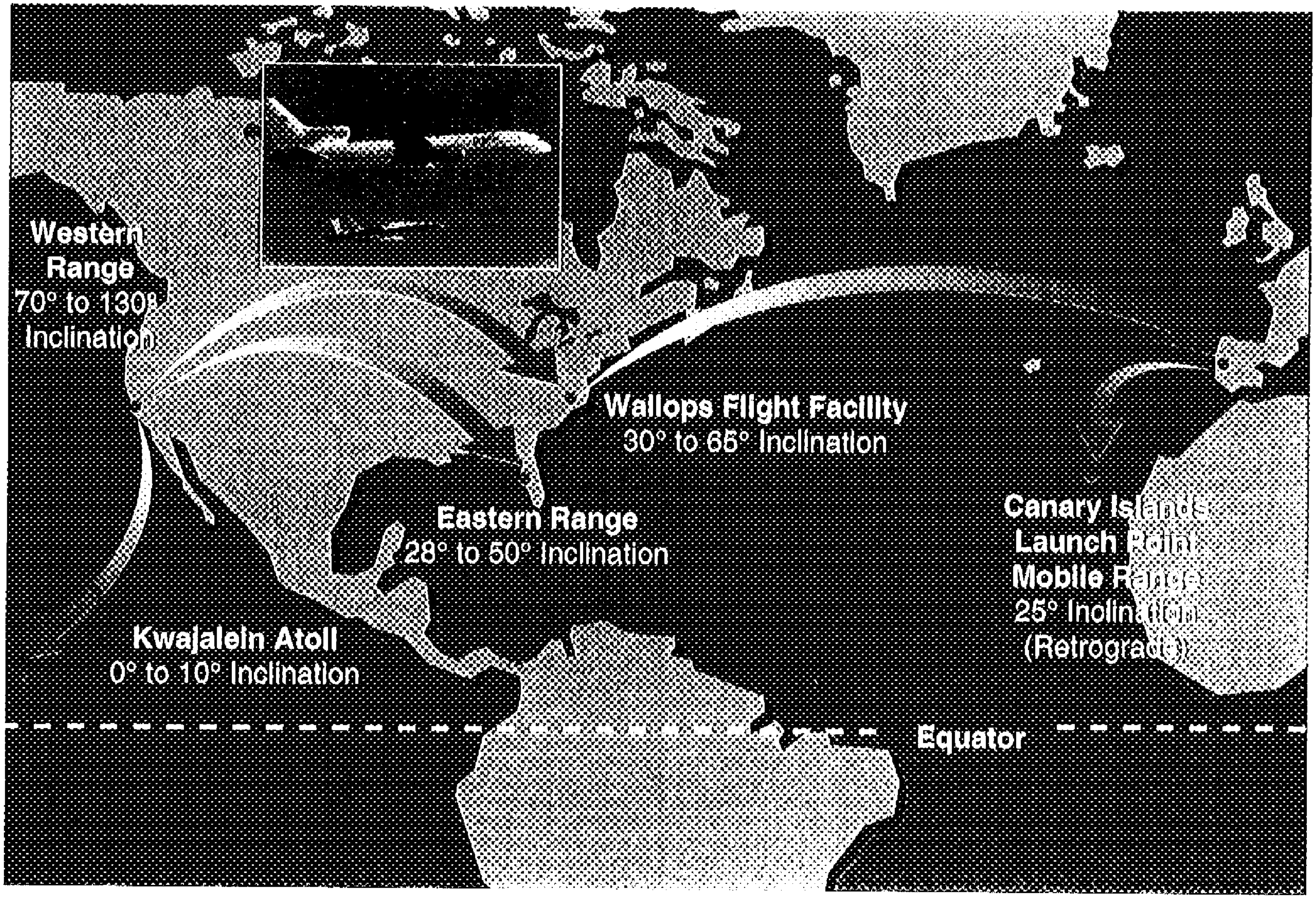


L-1011 Carrier Aircraft Payload Services and Launch Operation from Vandenberg.

Orbital Carrier Aircraft	Specifications
Max Taxi Weight	468,000 lbs
Max Gross Take-Off Weight	466,000 lbs
Max Landing Weight	368,000 lbs
Max Zero Fuel Weight	338,000 lbs
Operating Empty Weight	223,000 lbs
Captive Carry Mission Performance	
Mission Radius	1,000 nm
Ferry Range	3,000 nm
External Store Capacity	52,000 lbs
Operating Altitude	39,000 ft
Payload Deployment Speed	Mach 0.82

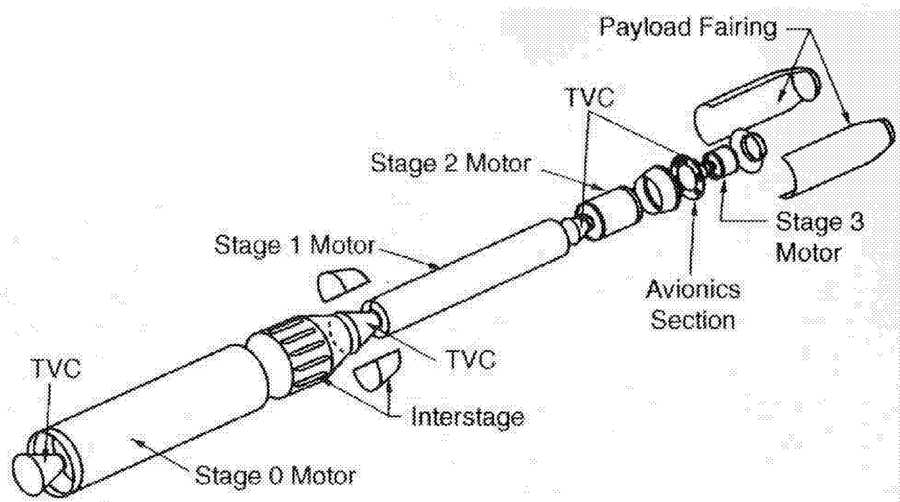
L-1011 Carrier Aircraft Performance.

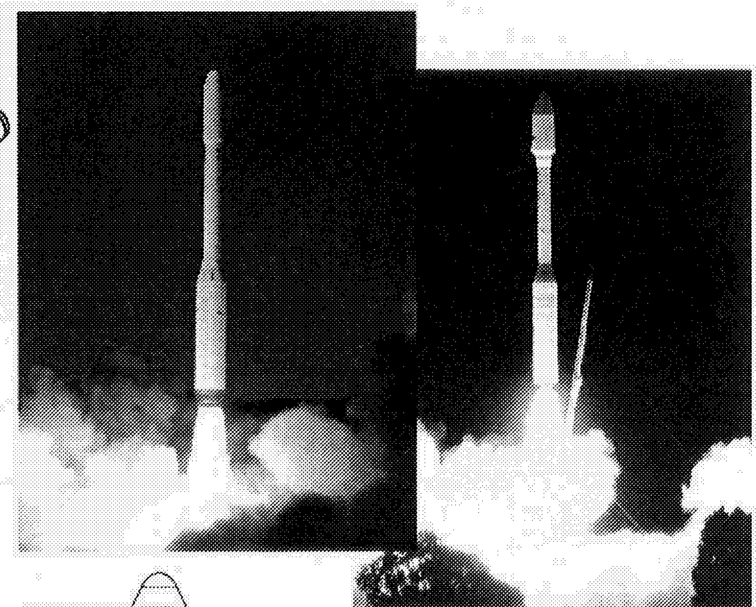
Pegasus Capable Launch Sites to Date



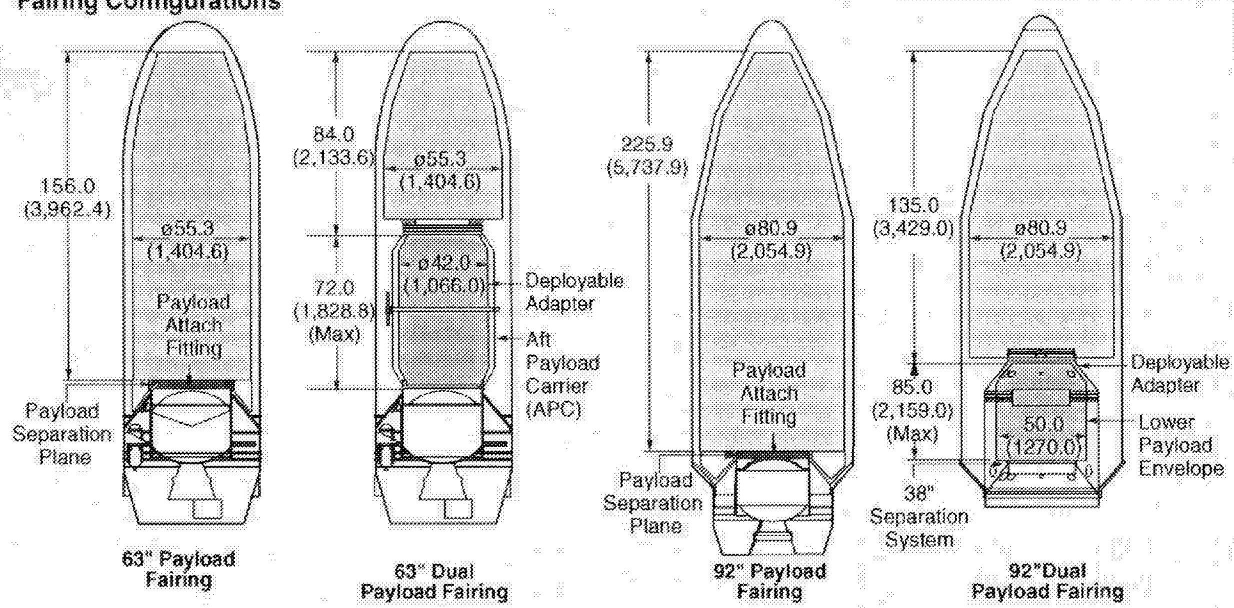
990406.02

Taurus Launch Vehicle





Fairing Configurations

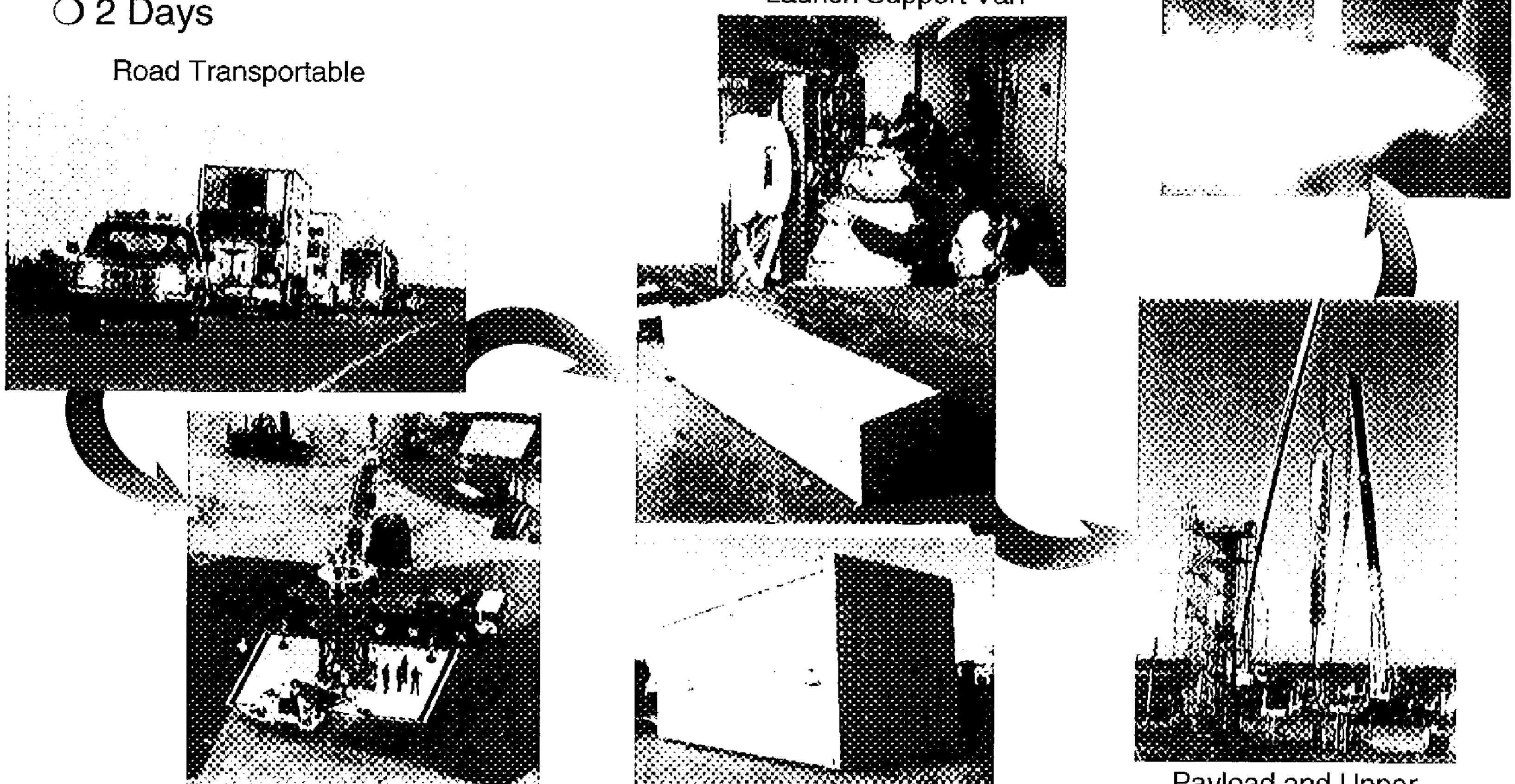


- Designed for Easy Transportability, Rapid Set-Up, and Launch from an Austere Site
- Capable of Quick Reaction Launch on Demand Scenarios Anywhere in the World

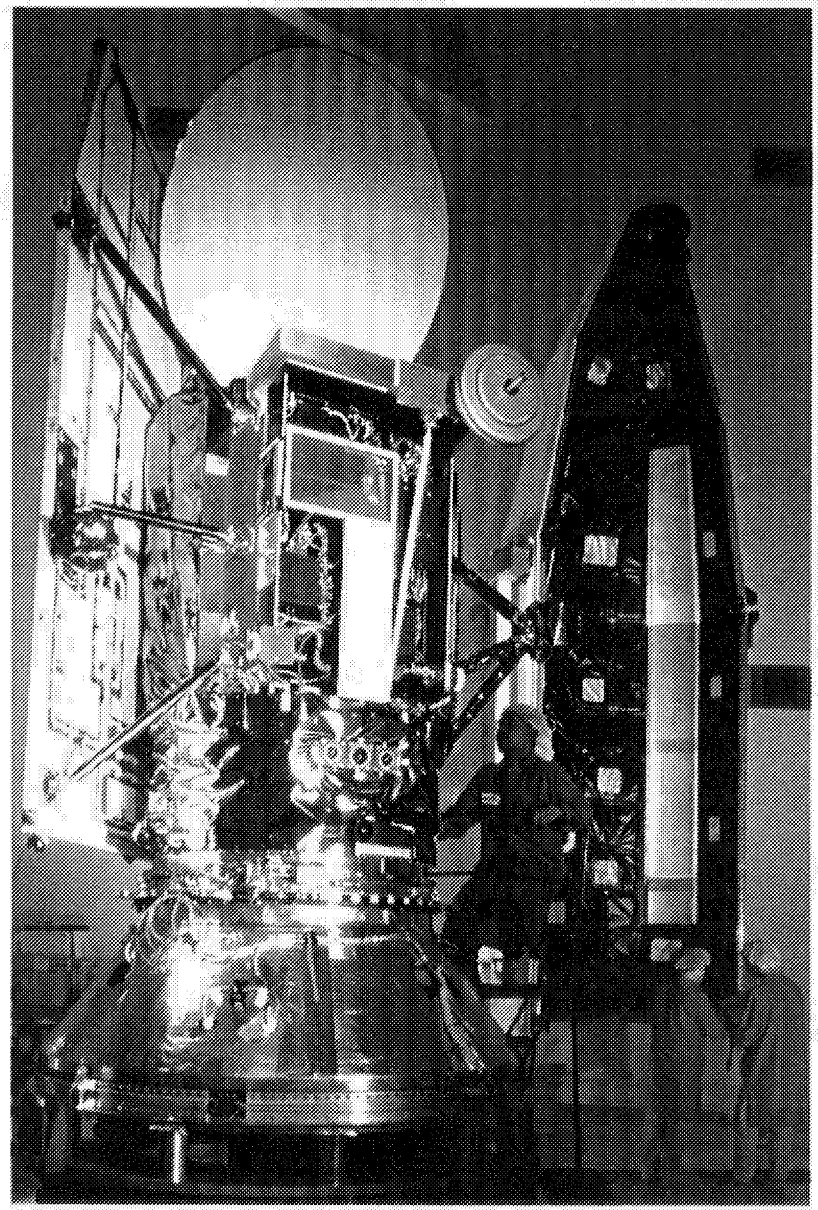
990408.01

Taurus Rapid Response Capability

- Launch on Demand Scenarios Easily Accommodated with Minimum Site Infrastructure
- Response Time Capability of
  - 8 Days
  - 5 Days
  - 2 Days



GeoSat Follow-On



990408.05

Orbital's Shared Launch Experience
(56 Payloads on 15 Launches)

Orbital

Launch	Date	Number of Payloads	Payloads	Payload Description
Completed Missions				
Pegasus F-1	April 1990	2	• Pegsat • Navysat	• Nondeployable Instrumentation Package • Deployable Experiment for Atmospheric Research
Pegasus F-2	July 1991	7	• 7 Microsats	• Multiple Deployable Satellites for Technology Demonstration
Pegasus F-3	February 1993	2	• SCD-1 • OXP-1	• Deployable Brazilian Communications Satellite • Deployable Satellite for Communications Demonstration
Pegasus F-4	April 1993	2	• ALEXIS • OXP-2	• Deployable U.S. Air Force Technology Demonstration Satellite • Nondeployable Commercial Communications Payload
Taurus T-1	March 1994	2	• DARPASAT • STEP-M0	• Deployable Classified Spacecraft • Deployable Satellite for Technology Demonstration • Load Bearing to Optimize Mass and Volume
Pegasus F-6	June 1994	2	• STEP-M1 • FX-A	• Deployable U.S. Air Force Technology Demonstration Satellite • Nondeployable NASA Hypersonic Research Experiment
Pegasus F-8	April 1995	3	• FM-1 • FM-2 • OrbView-1	• Deployable Communications Satellite • Deployable Communications Satellite • Deployable Remote Sensing Satellite • All Load Bearing to Optimize Mass and Volume
Pegasus F-14	November 1996	2	• SAC-B • HETE	• Dual Deployable NASA Scientific Satellites • Non Load Bearing Using the DPAF
Pegasus F-15	April 1997	2	• MINISAT 01 • Celestis	• Deployable Spanish Scientific Satellite • Nondeployable Tertiary Commercial Payload
Pegasus F-19	December 1997	8	• ORBCOMM-1 (FM 5-12)	• Initial Constellation Launch to Deploy 8 Microstar Satellites • Load Bearing to Optimize Mass and Volume
Taurus T-2	February 1998	4	• GFO • FM-3 • FM-4 • Celestis	• Deployable Ocean Altimetry Spacecraft for the U.S. Navy • Deployable Microstar Spacecraft for ORBCOMM • Deployable Microstar Spacecraft for ORBCOMM • Nondeployable Commercial Tertiary Payload
Pegasus F-20	February 1998	2	• SNOE • BATSAT (T-1)	• NASA Deployable Student Payload Under STEDI Program • Commercial Deployable Microstar Satellite • Secondary Load Bearing to Optimize Mass and Volume
Pegasus F-22	August 1998	8	• ORBCOMM-2 (FM 13-20)	• Second Constellation Launch to Deploy 8 Microstar Spacecraft • All Load Bearing to Optimize Mass and Volume
Pegasus F-23	September 1998	8	• ORBCOMM-3 (FM 21-28)	• Third Constellation Launch to Deploy 8 Microstar Spacecraft • All Load Bearing to Optimize Mass and Volume
Pegasus F-24	October 1998	2	• SCD-2 • Wing Glove	• Deployable Commercial Communications Satellite for Brazil • Nondeployable NASA Hypersonic Research Experiment
Planned Missions				
Pegasus	1999	2	• TERRIERS • MUBLCOM	• NASA Deployable Student Payload Under STEDI Program • Commercial Deployable Microstar Satellite • Secondary Load Bearing to Optimize Mass and Volume
Taurus	1999	2	• KOMPSAT • ACRIM	• Commercial Deployable Primary Remote Sensing • NASA Deployable Secondary Payload Using the APC
Pegasus	1999	8	• ORBCOMM-4 (FM 29-36)	• Fourth Constellation Launch to Deploy 8 Microstar Spacecraft • Equatorial Launch
Taurus	2000	Multiple	• OrbView-4 • Open	• Commercial Remote Sensing Satellite • Available for Booking

990326.02

Making Space Available

Shared Payload Launch Opportunities

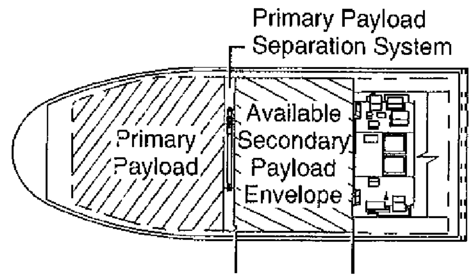
To date, Orbital has successfully placed 52 payloads into orbit on 13 Pegasus and Taurus shared launches. Presently, Orbital has launch opportunities available on our launch systems. These launches have capacity available for co-passenger payloads matching the orbit, schedule, mass, and volume parameters, shown in the *Table A* below. Payloads that can accept these mission parameters should contact Orbital to verify technical compatibility and obtain a launch agreement. In addition, Orbital maintains a listing of known missions that are searching for complementary payloads to share a launch. These missions are listed in *Table B*.

If any of these payload parameters match your specific needs, you are invited to contact Orbital's Launch Systems Group business development to further assess mission compatibility and a possible launch assignment on Pegasus or Taurus.

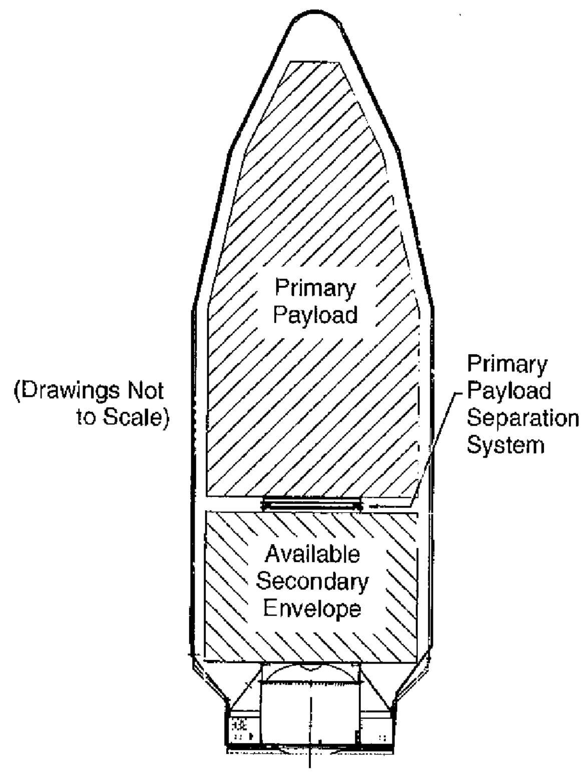
- Check our Orbital launch opportunities on our web site (www.Orbital.com)
- Look for compatible ride share partners
- Register your mission to be considered

A

Mission	Orbit	Launch Date	Mass Available Volume Available
Pegasus LV-P010	0-5° 550-700 km	Early 2000	• 20-75 kg
Taurus LV-T011	Sun-Synchronous 470 km 10:50 a.m.	Mid 2000	• 300 kg • 110 cm Dia x 153 cm Height
Pegasus LV-P012	0-10° 550-650 km Circular	2001	• 100 kg Estimate
OSP LV-013	Sun-Synchronous 12:00 p.m. ±2 hrs or 50-95°, 500-600 km	Early 2000	• 150 kg + • 66 cm dia x TBD Length
Pegasus LV-P014	45° Inclination 825 km	Mid 2000	• 140 kg • Cone, 100 cm at Base, 75 cm at Top • 95 cm Height (23" Interface Assumed)
Pegasus LV-015	45° Inclination 825 km	Late 2000	• 140 kg • Cone, 100 cm at Base, 75 cm at Top • 95 cm Height (23" Interface Assumed)



Pegasus Shared Launch Configuration



Taurus Shared Launch Configuration

B

Mission	Inclination Altitude Nodal Crossing	Launch Date	Launch Mass & Volume Available
P-107	Sun-Synchronous 550-650 km 6 a.m. ± 2 hrs	Mid 2000	• 100 Kg • 111.7 cm dia. x 55.6 cm height
P-108	Sun-Synchronous 613 km Circular	2002	• 110 - 275 Kg • 109.2 cm dia. x 177.8 cm height

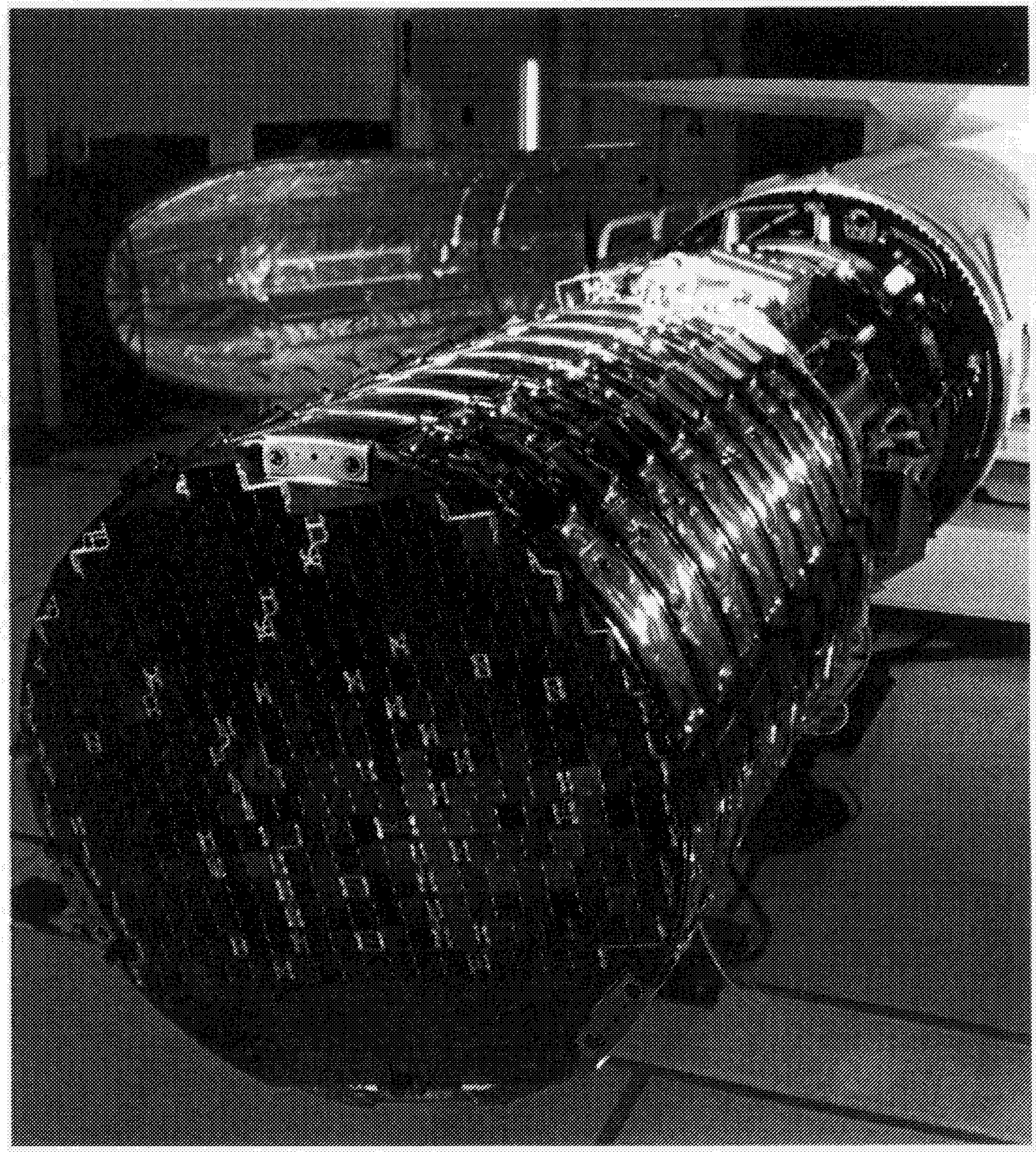
Orbital

For further information contact the New Business office at (703) 404-7400

www.orbital.com

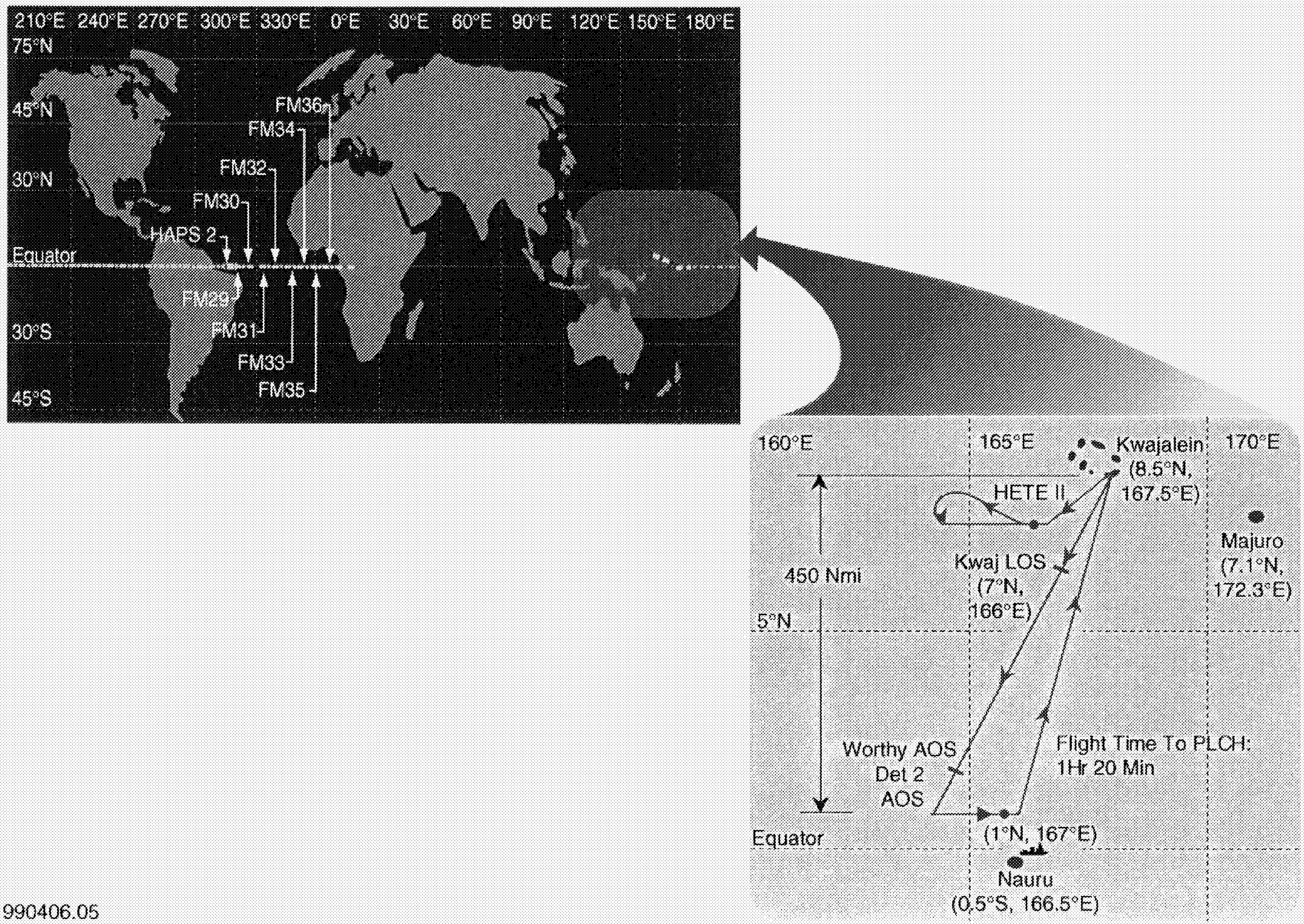
ORBCOMM 8 Stack

Orbital



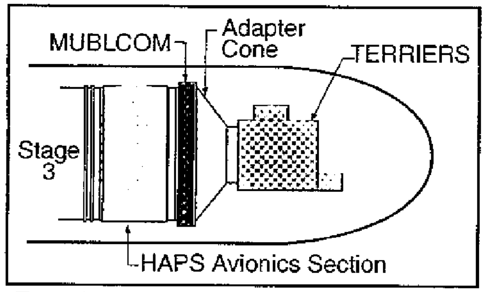
990408.06

Pegasus® Equatorial Launch from Kwajalein Atoll

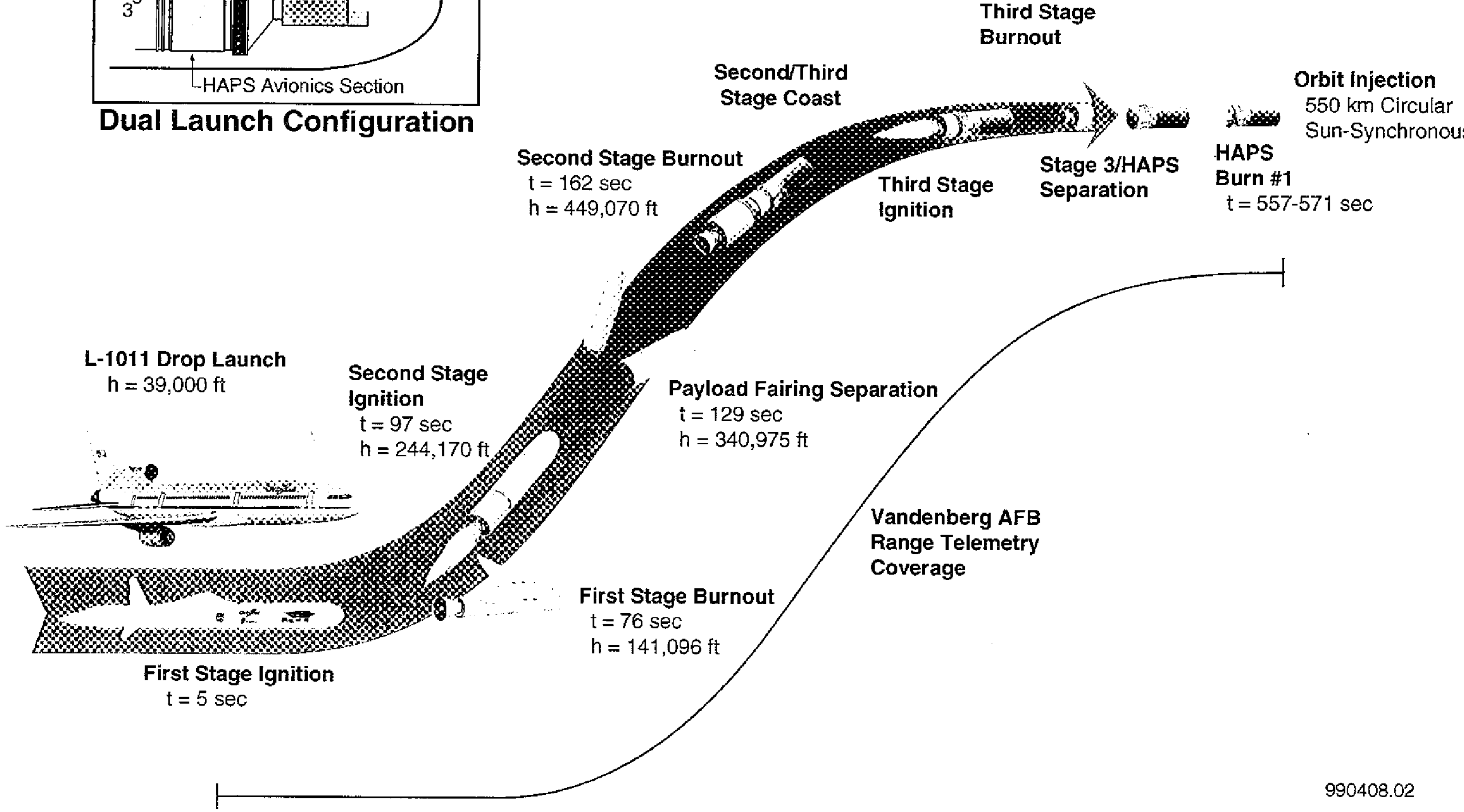


990406.05

Pegasus® TERRIERS/MUBLCOM Mission Profile

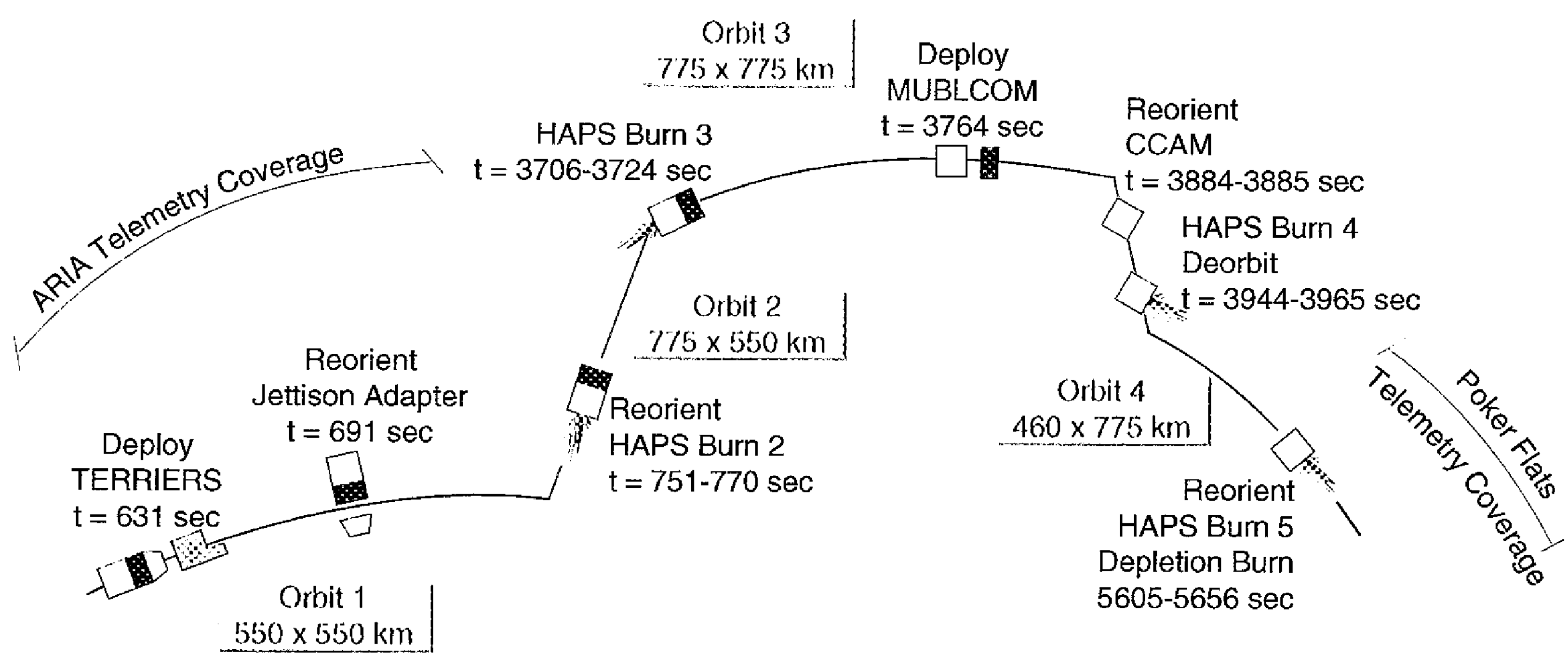


Dual Launch Configuration



990408.02

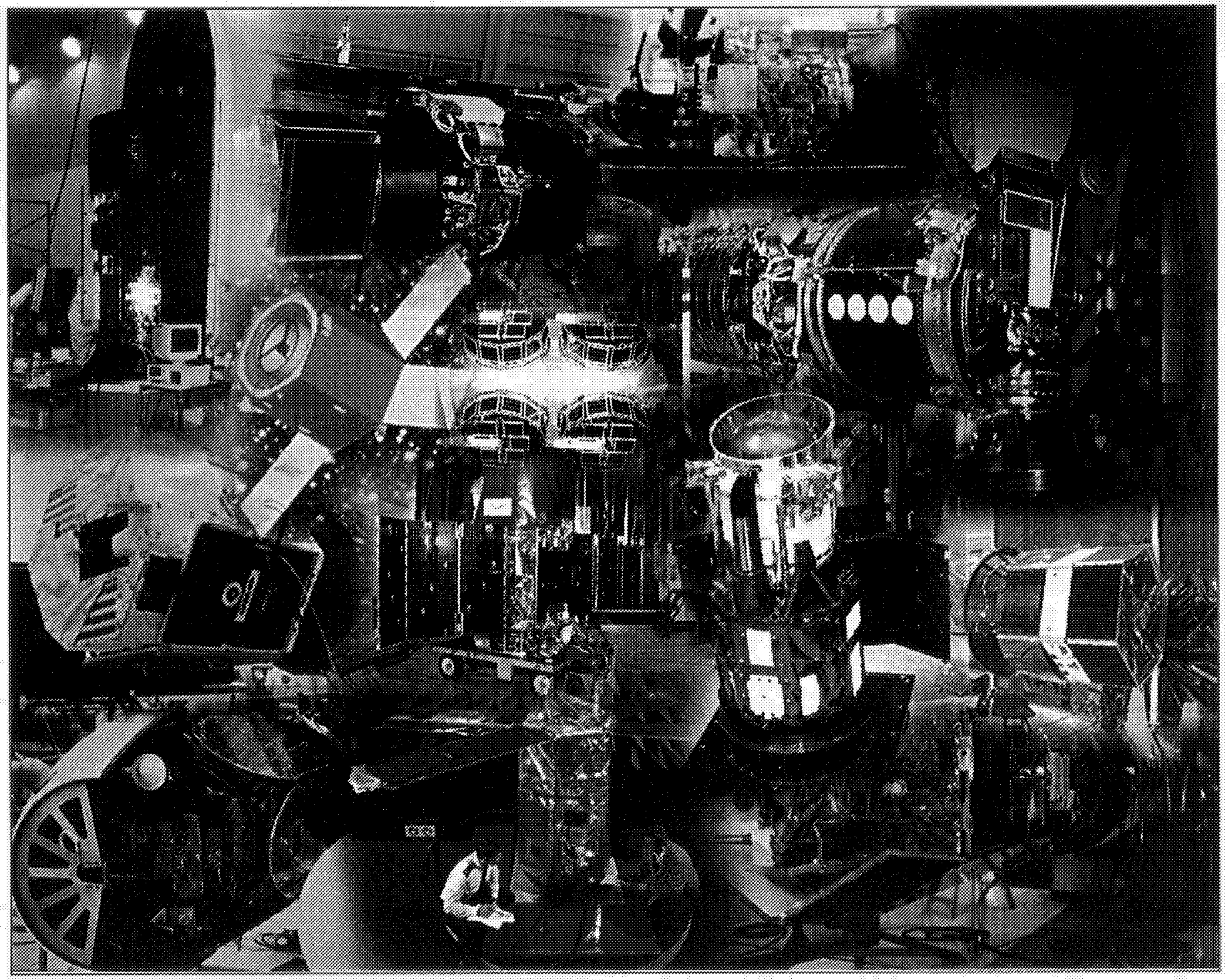
Pegasus®/TERRIERS/MUBLCOM Mission Profile (Cont'd)

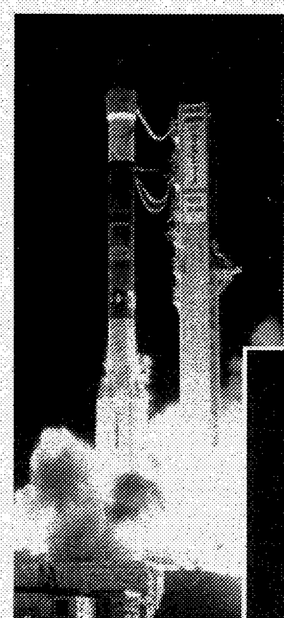


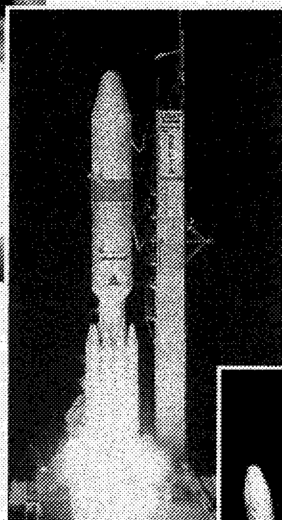
990406.12a

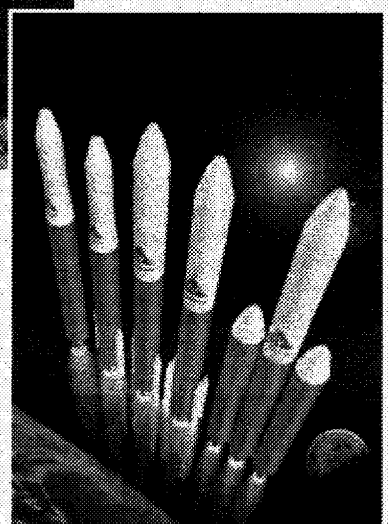
Commitment to Mission Success

Orbital









NASA/NRO Rideshare Conference Delta Launch Services

Bill Files

Expendable Launch Systems
Huntington Beach, California

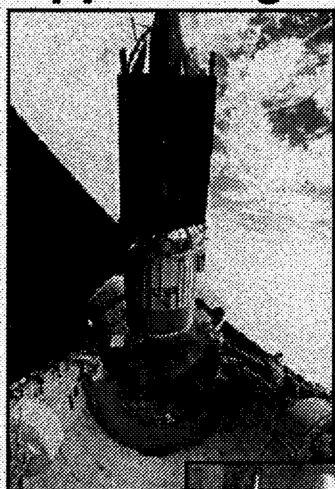
April 15-16, 1999

BOEING

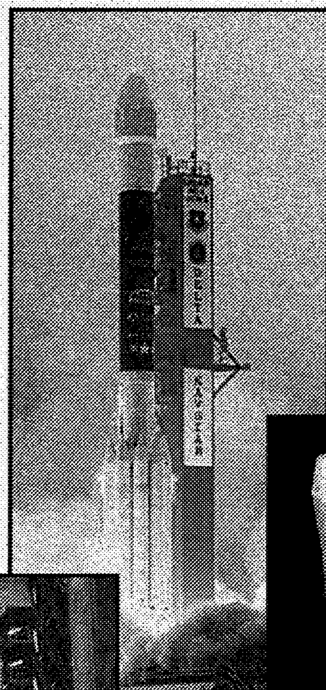
9P237000 - 0
4/13/99/BF

Expendable Launch Systems

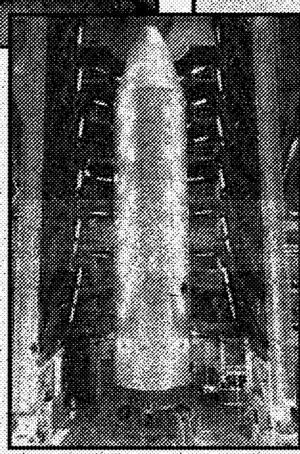
Inertial Upper Stage



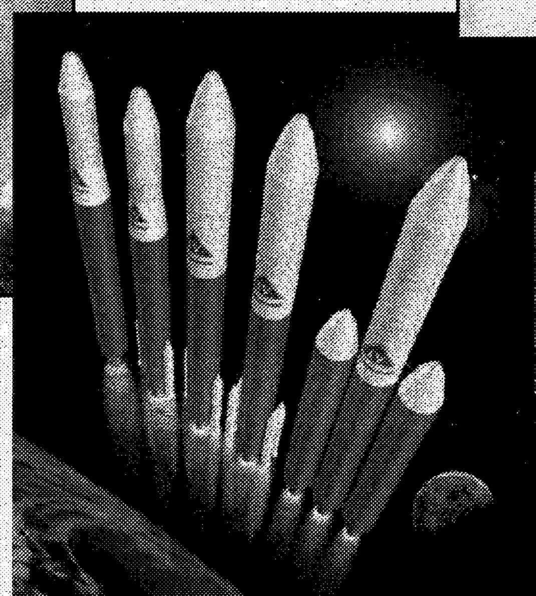
Delta II



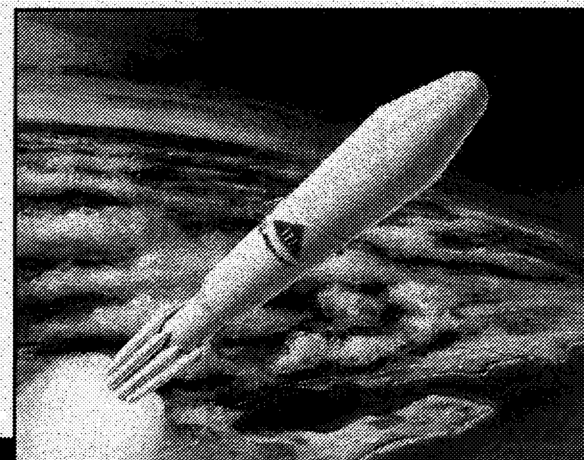
Titan Fairing



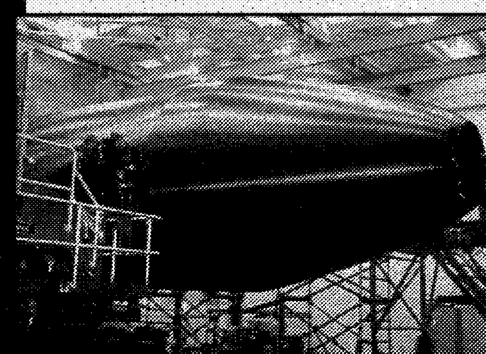
Delta IV



Delta III



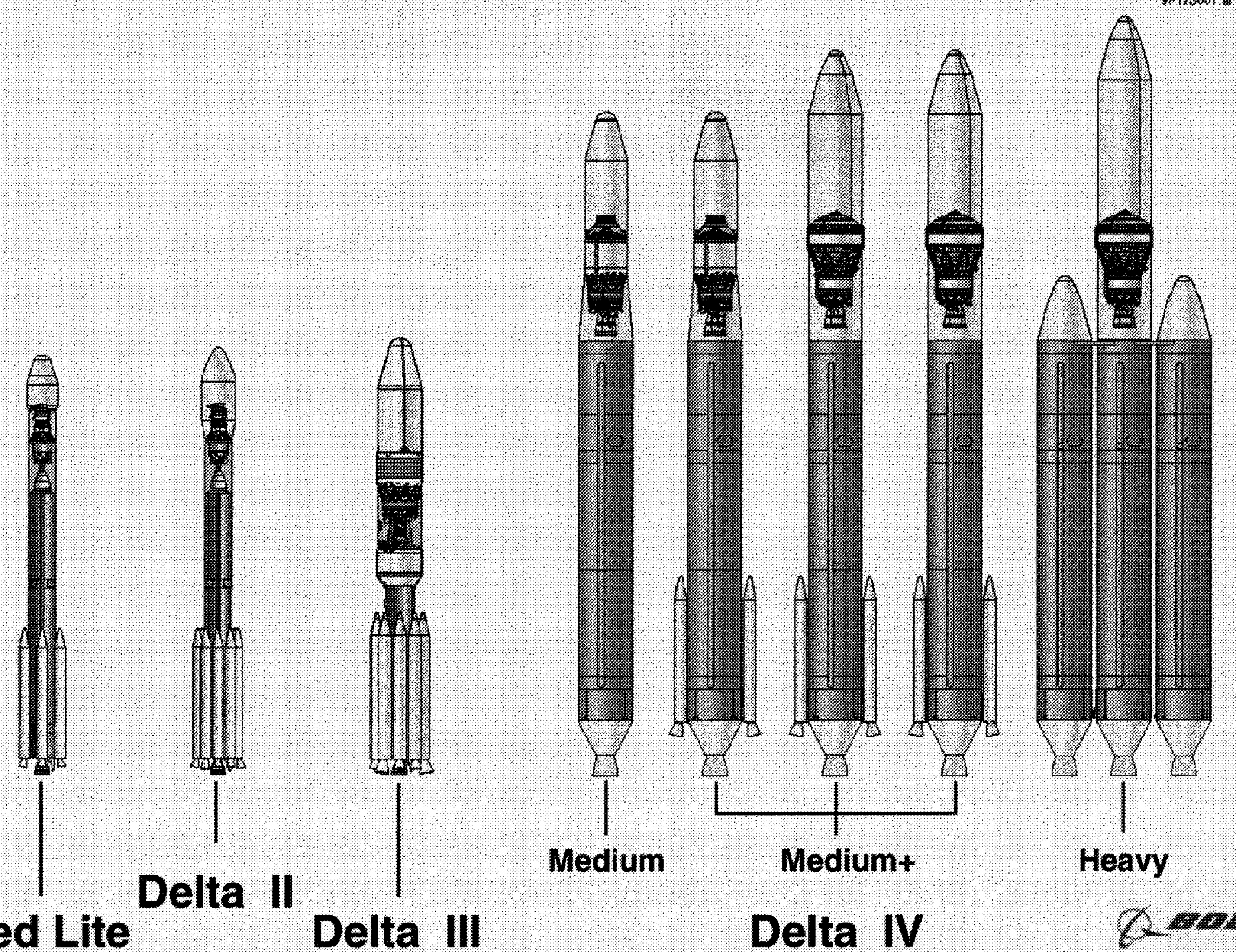
Sea Launch



BOEING

9P237000 - 1
4/13/99/BF

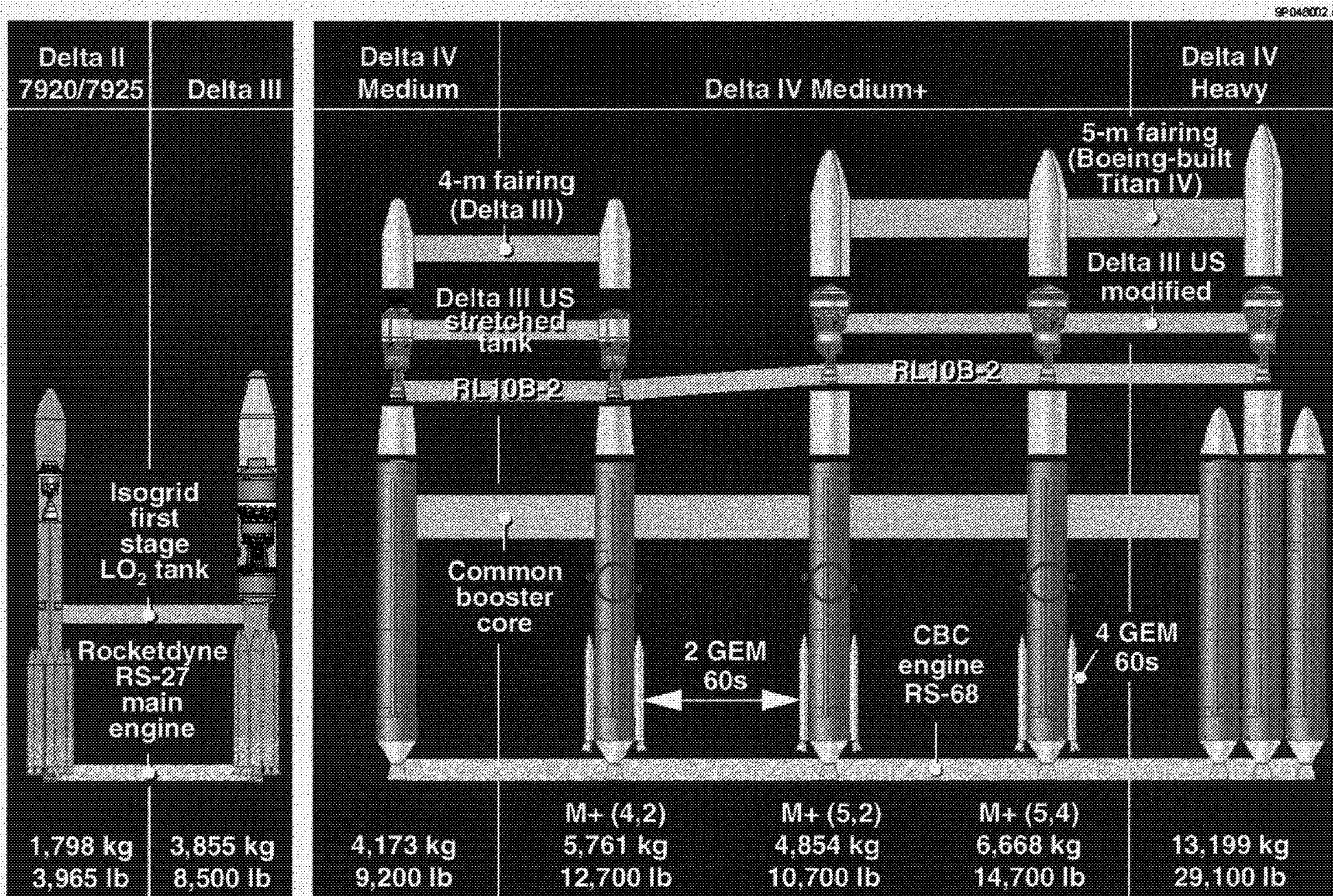
Delta Launch Vehicle Family Meets New and Emerging Customer Requirements



BOEING

9P237000 - 2
4/13/99/BF

Delta Family Spans Entire Payload Range

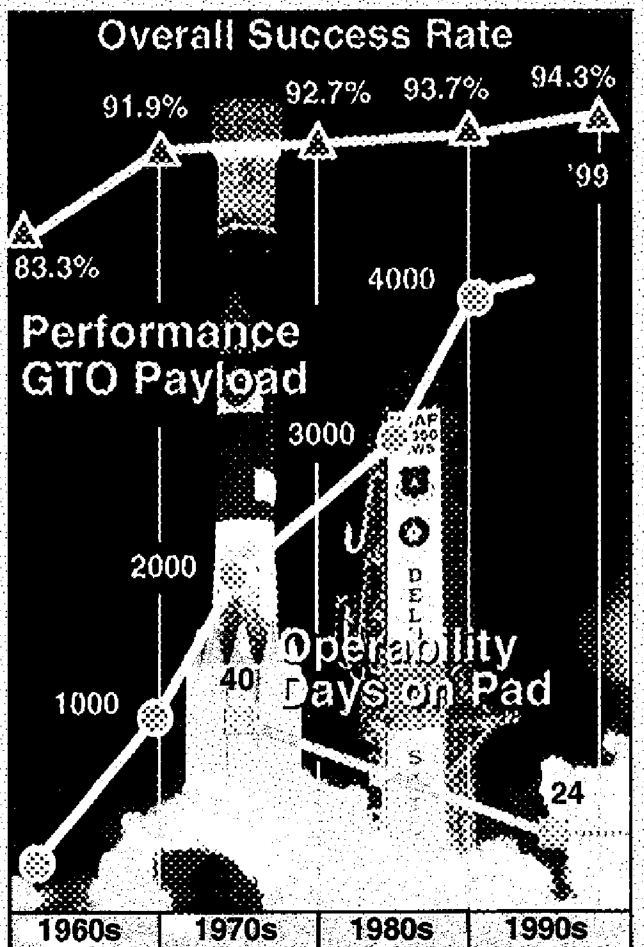


Performance to GTO (185 km x 35,786 km x 27°)

BOEING

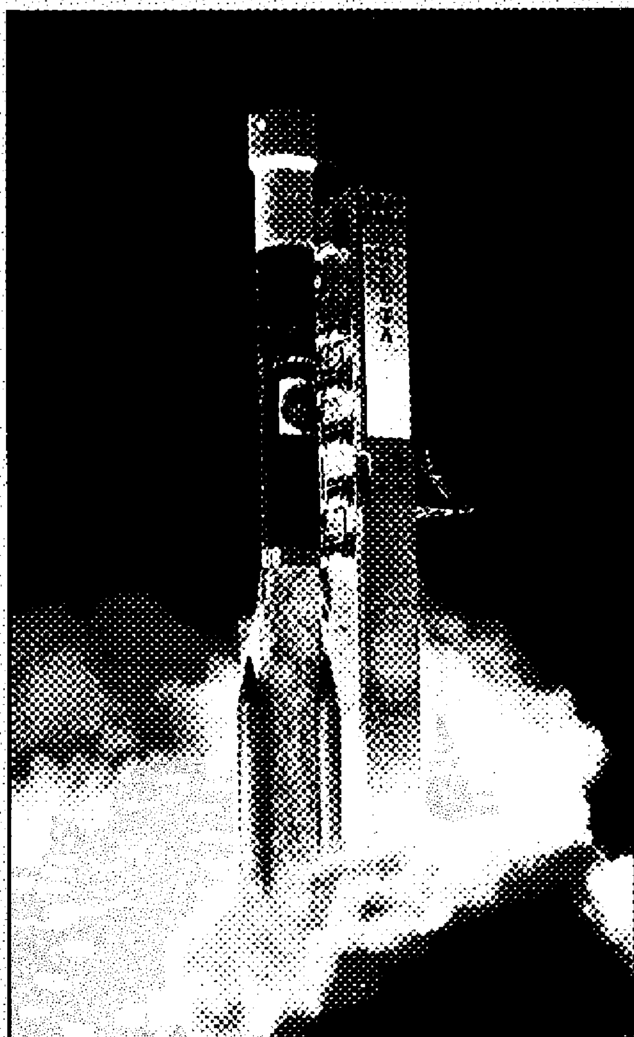
9P237000 - 3
4/13/99/BF

Delta II Program Summary



- The western world's most reliable launch vehicle
  - 96.9% success since Oct 1977 (127 out of 131 launches)
- One standard of quality for government and commercial customers
  - 12 launches in 1998 (2 government, 10 commercial)
  - 15 launches planned for 1999 (8 government, 7 commercial)
- Secondary payloads successfully flown on 21 missions for Air Force, NASA, and SDIO
  - First flight on Pioneer-C December 1967
  - Last flight on P91-1 Argos February 1999

NASA Med-Lite Program

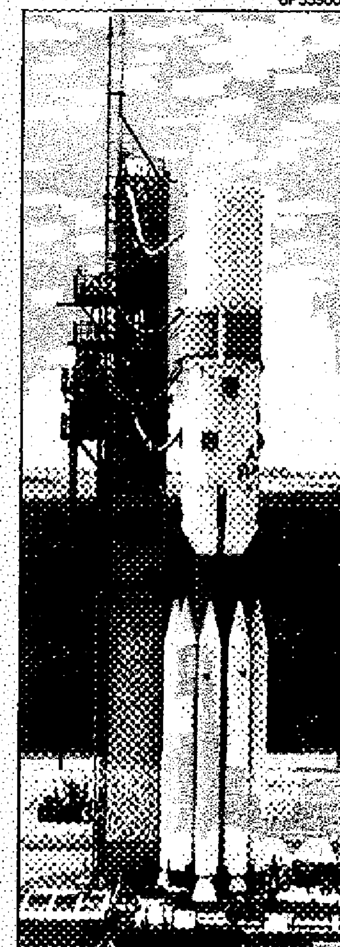


- Medium Light Expendable Launch Service initiated in February 1996
- Status to date
  - Flown (4): Deep Space 1, Mars Orbiter '98, Mars Lander '98, Stardust
  - On contract (6): FUSE, IMAGE, EO-1/SAC-C, MAP, Genesis, and Mars Lander '01
  - Secondary payload SEDSAT flown on Deep Space 1 October 1998

Delta III Program

- Delta III program approach
  - Commercially developed by Boeing
  - Address launch vehicle market needs for spacecraft up to 3.8 metric tons
- Delta III evolution
  - Based on existing Delta II
  - New cryogenic upper stage and fairing
  - Launch base modifications
- Major Delta III team members
  - Alliant Techsystems
  - Boeing Rocketdyne
  - Pratt & Whitney
  - Mitsubishi Heavy Industries

8P559001

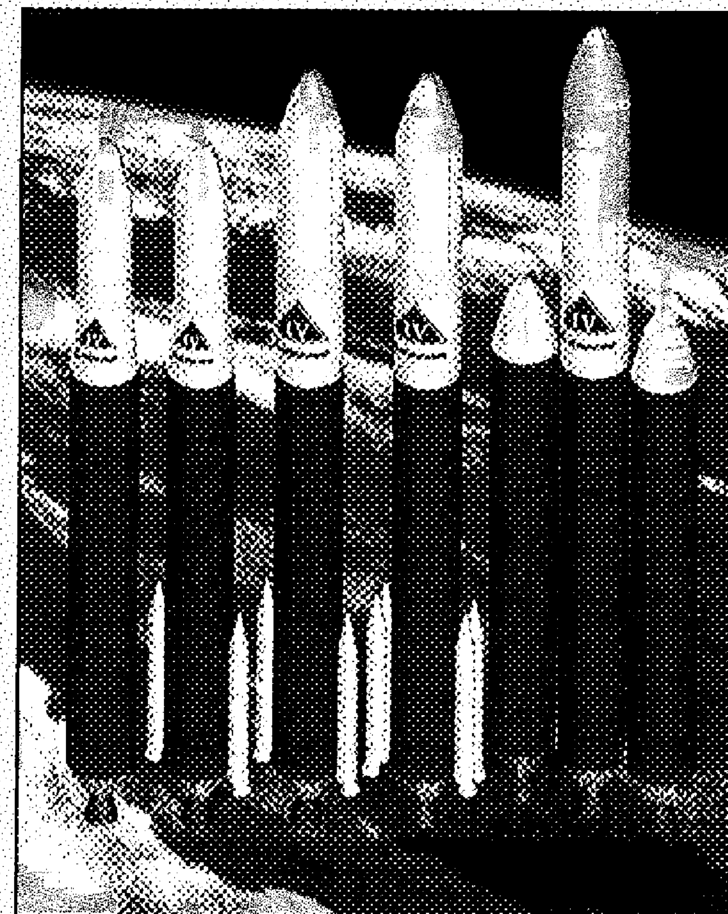


BOEING

9P237000 - 6
4/13/99/BF

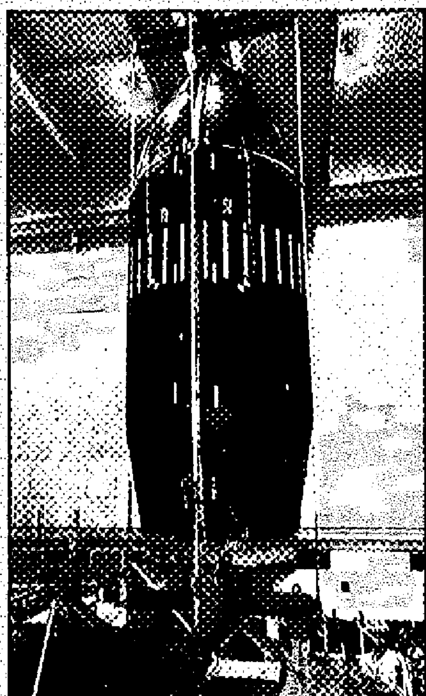
Evolved Expendable Launch System/Delta IV

- Next evolution of the highly reliable Delta vehicle
- Satisfies government and commercial requirements
- Modular family of launch vehicles from Medium to Heavy capability
- Dual coast capability
  - CCAS ILC 2nd qtr CY2001
  - VAFB ILC 4th qtr CY2002
- Initiating secondary payload study for U.S. Air Force



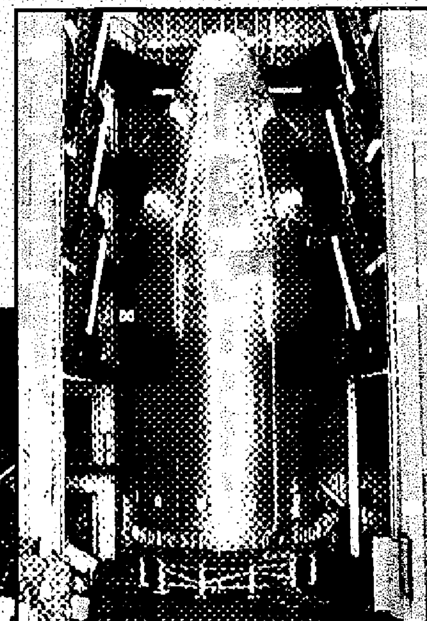
BOEING

Delta IV Uses Boeing-Manufactured Stretched Delta III and Titan IV Fairings



- Delta II's 10-ft-dia composite fairing
- Successfully flown 13 times
  - 11 for Motorola Iridium®
  - 2 for Globalstar

- Delta III's 4-m-dia composite fairing
- Used on Delta IV Medium, Delta IV Medium-Plus



- Boeing manufactured 200-in.-dia aluminum Titan IV fairing
- 100% success rate over the 24 Titan IV missions flown

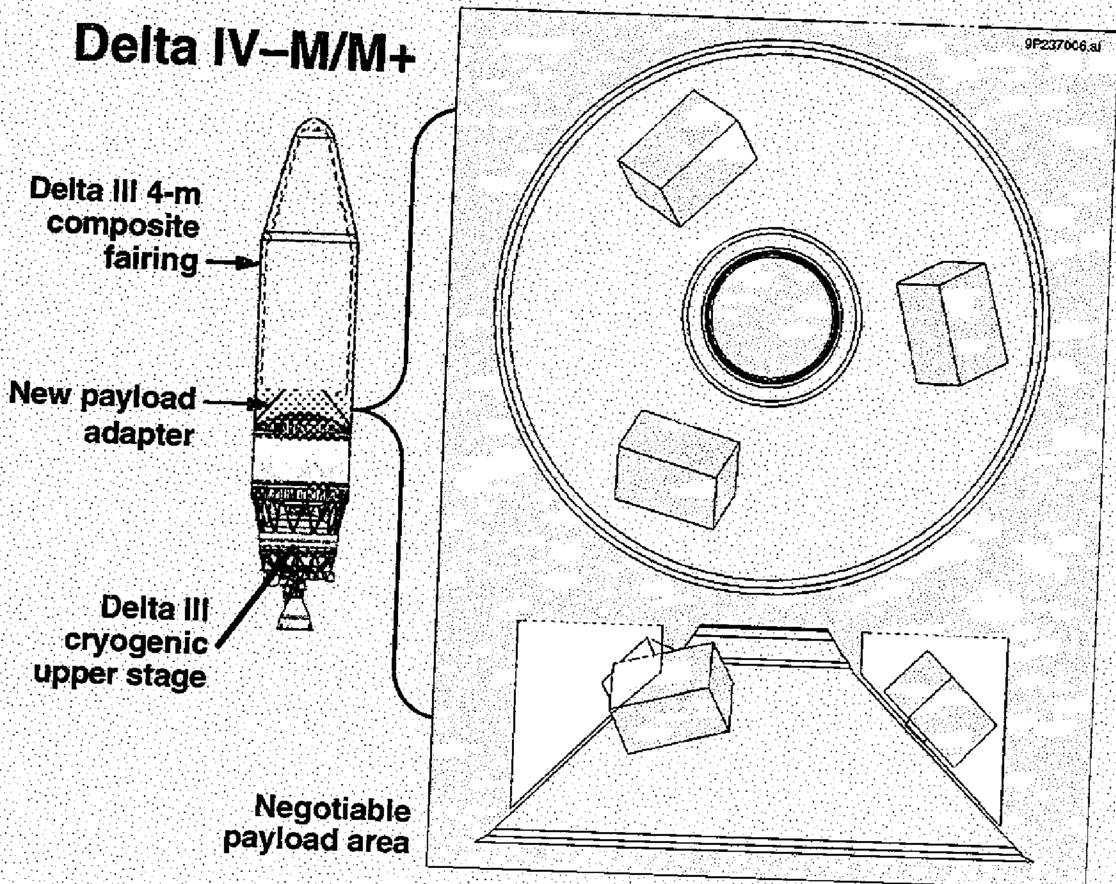
As of 01 October 1998

BOEING

9P237000 - 8
4/13/99/BF

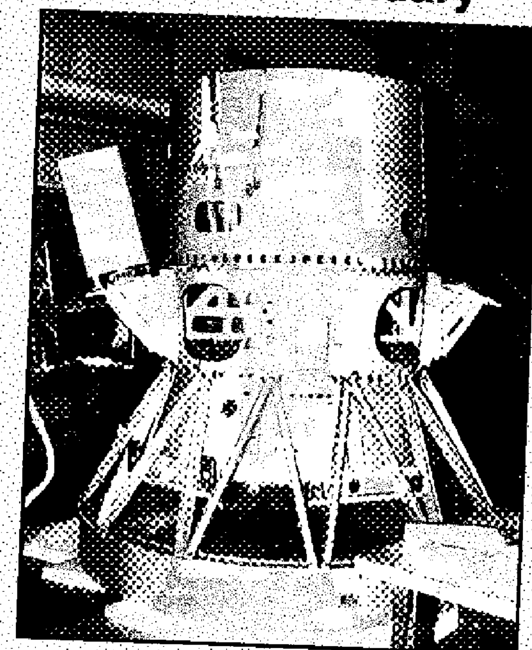
Secondary Payload Accommodations

Delta IV–M/M+



Payload attach fitting

P91-1 Secondary



Delta II-7920
Guidance Section

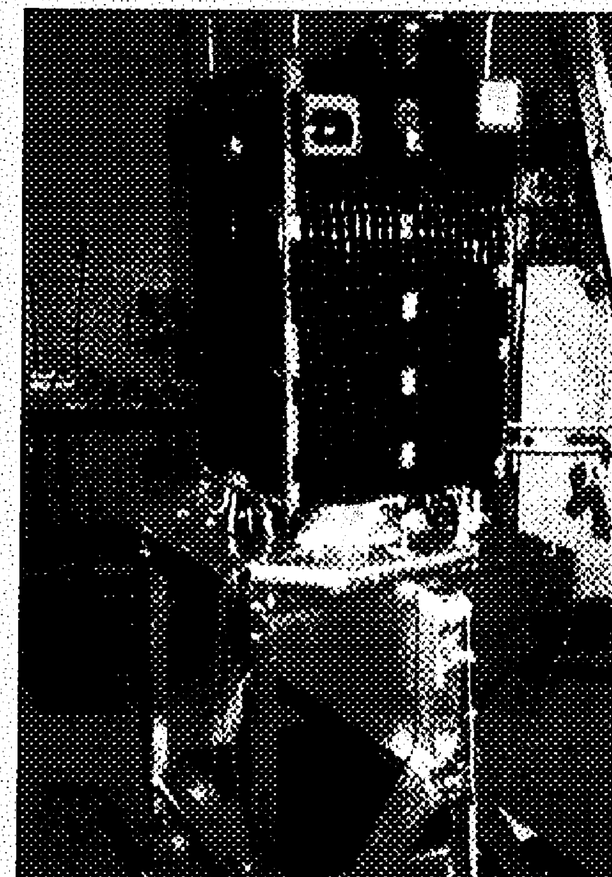
BOEING

9P237000 - 9
4/13/99/BF

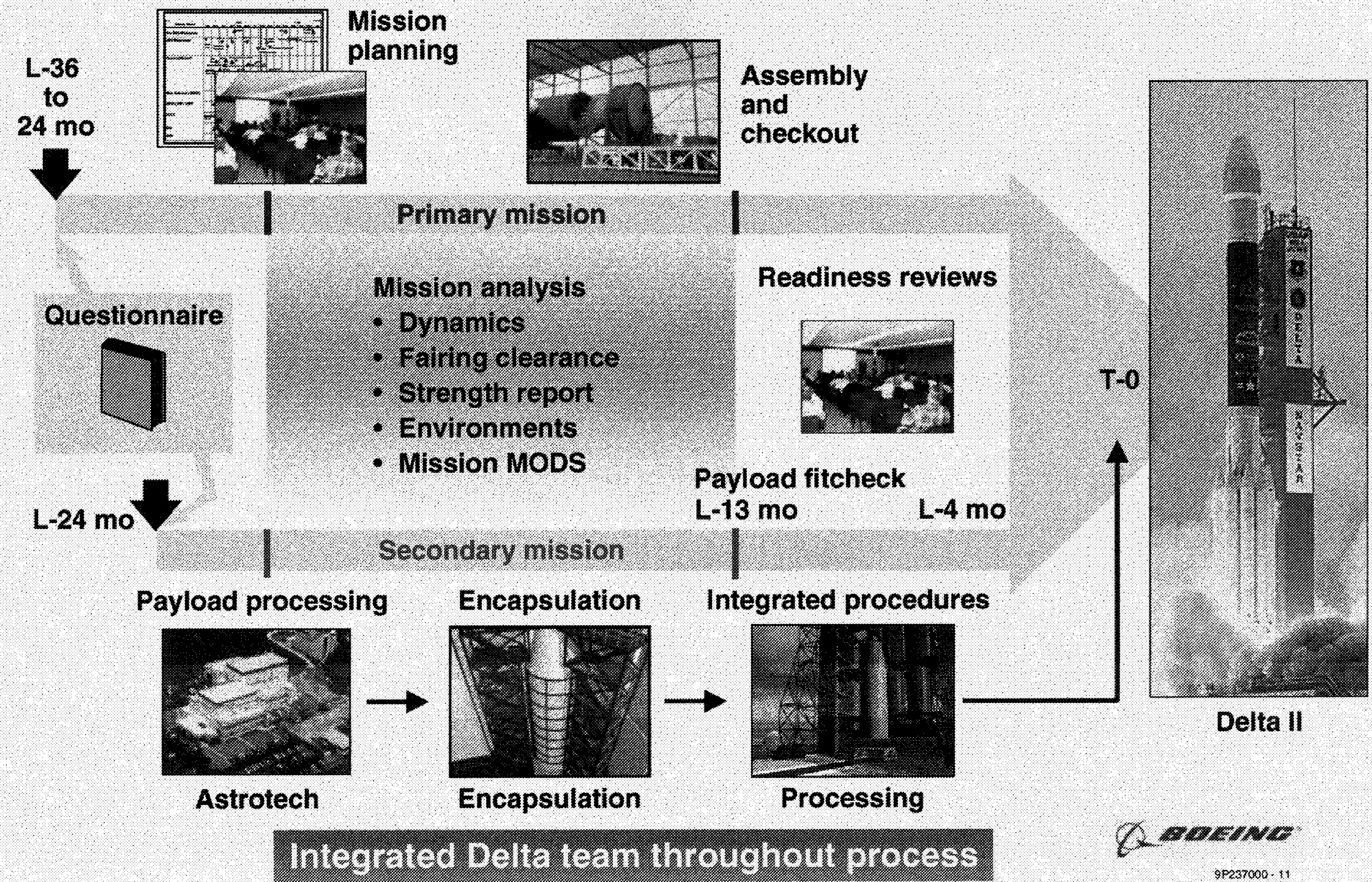
Secondary Payload Considerations

- Presents no hazard to primary payload
- Requires approval of primary payload program manager
- Satisfies primary payload mission orbit requirements
- Delta has excess performance margin
  - Secondary mission withdrawn if margin reduced
- Compatible with launch times
- Maintains primary payload clearance envelope
- Keeps launch services separate from primary mission
- Complies with range safety requirements

Oersted



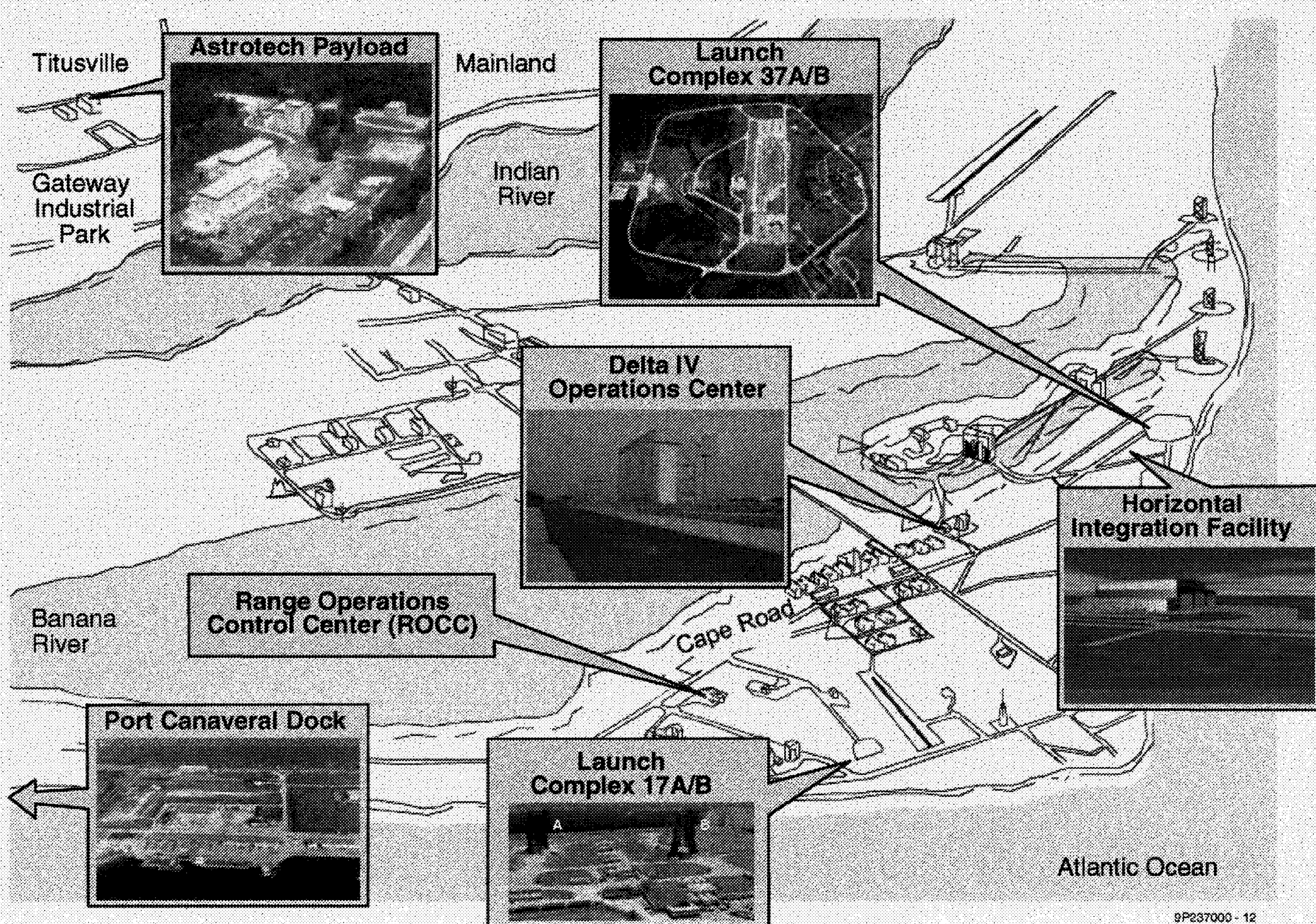
Secondary Payload Integration Parallels Primary Mission Process



BOEING

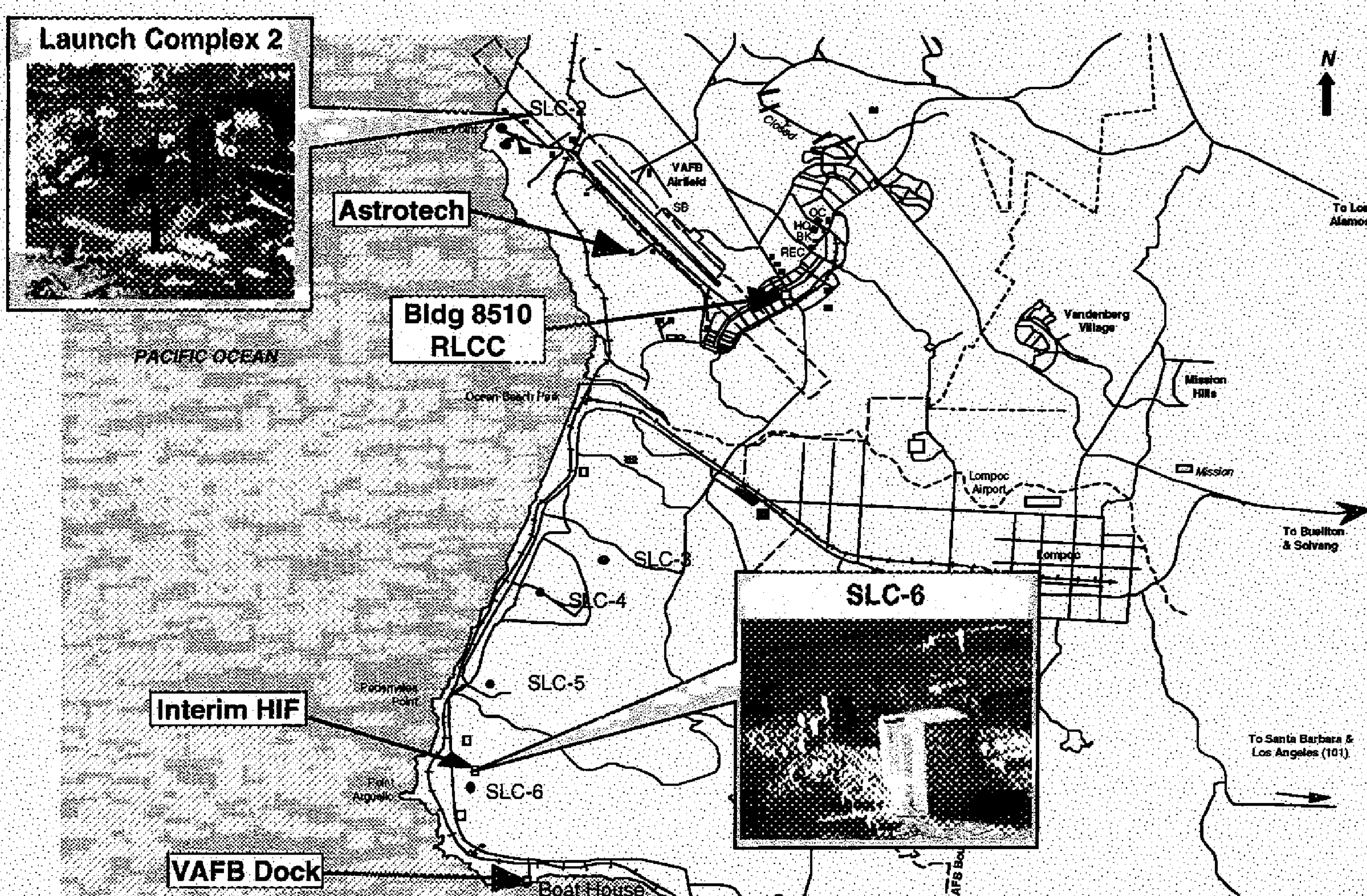
9P237000 - 11
4/13/99/BF

Cape Canaveral Air Station Facilities



9P237000 - 12
4/13/99/BF

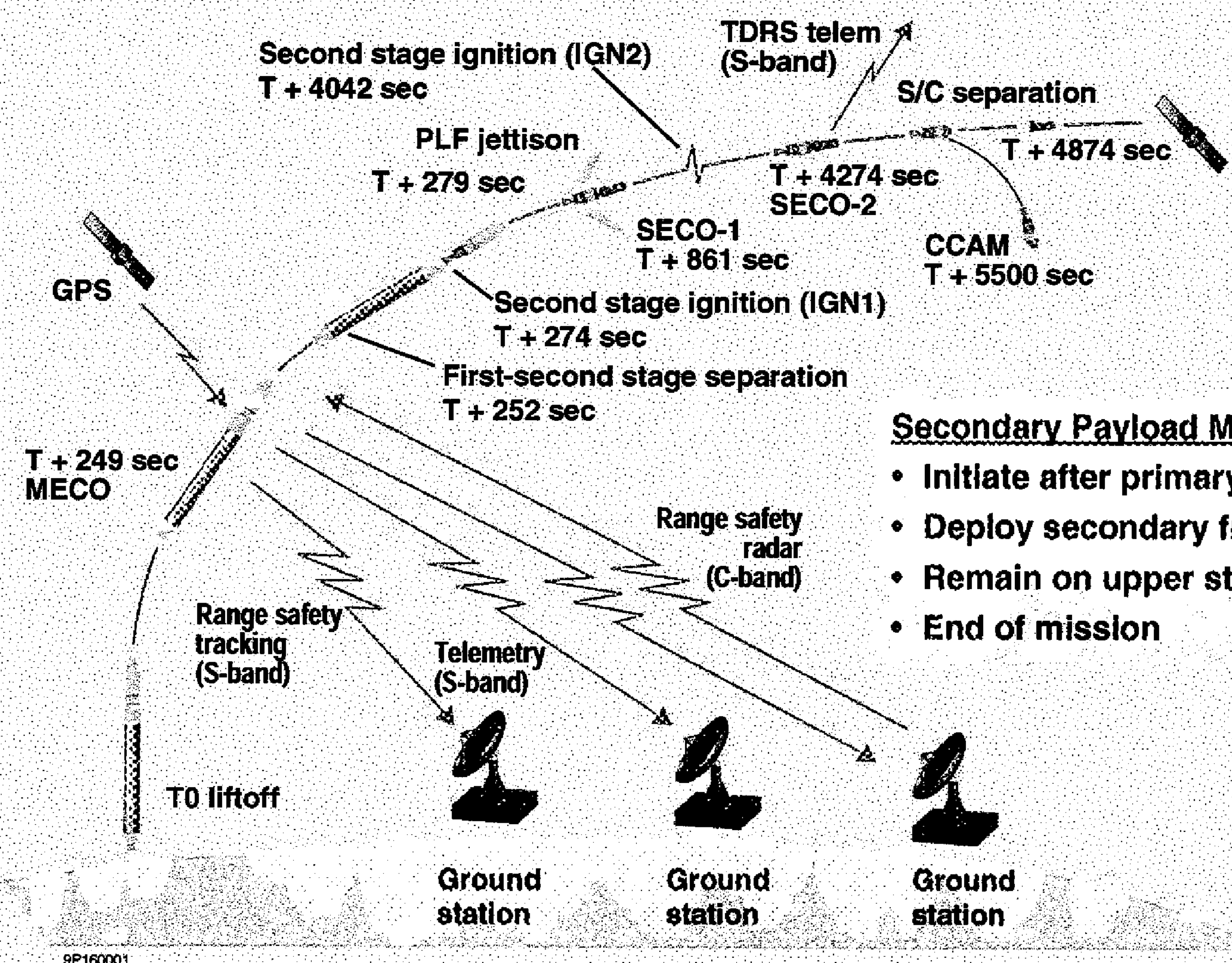
Vandenberg Air Force Base Facilities



BOEING

9P237000 - 13
4/13/99/BF

Flight Sequence of Events Delta IV Medium



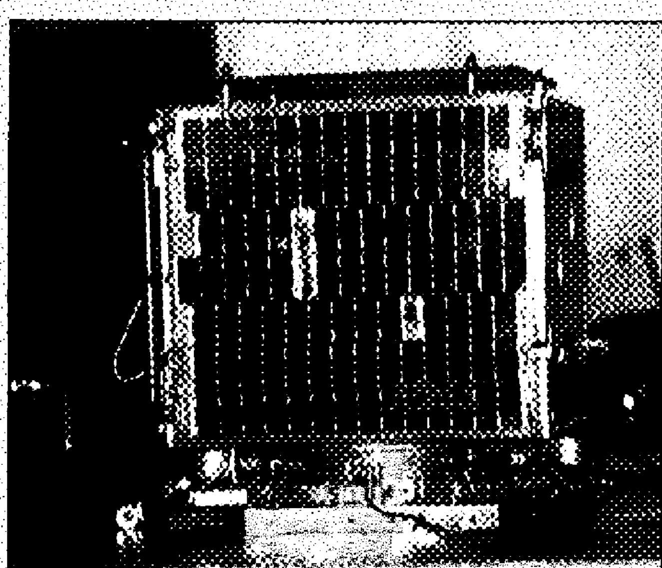
Secondary Payload Mission Sequence

- Initiate after primary mission separation
- Deploy secondary from upper stage
- Remain on upper stage
- End of mission

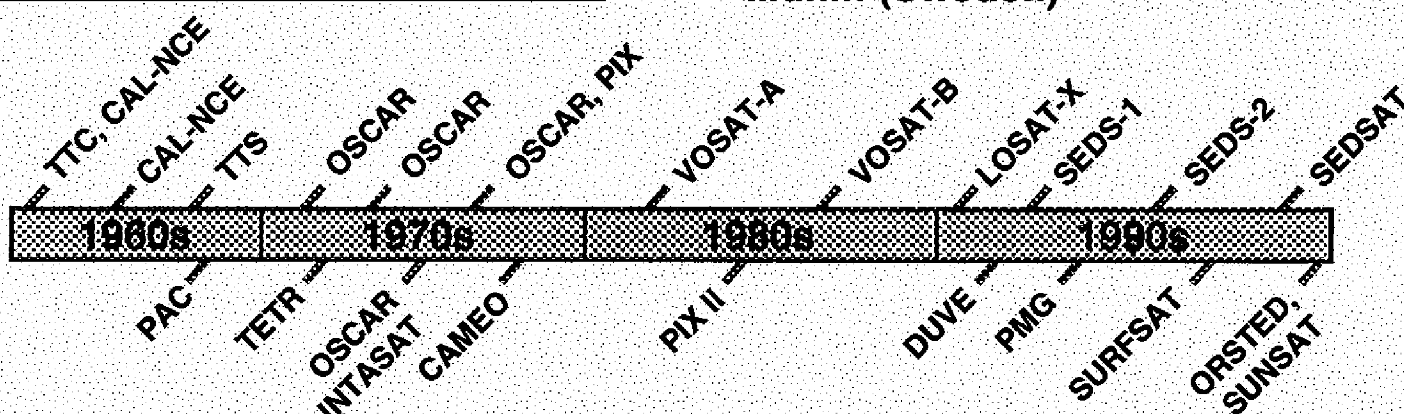
BOEING

9P237000 - 14
4/13/99/BF

Delta Program has a Long History Of Secondary Payload Mission Successes



- Secondary payload must be compatible with primary mission
- Generally two year mission integration cycle
- Boeing conducting study on EELV secondary payload adapter
- Next secondary mission for NASA is May 1999
  - Citizen Explorer (University of Colorado)
  - Munin (Sweden)



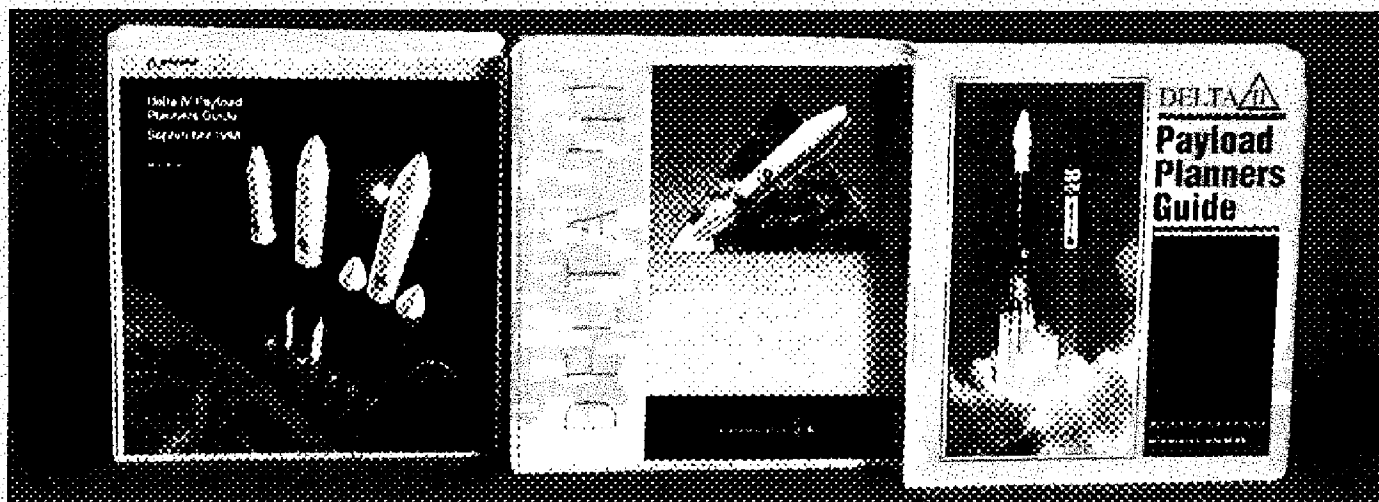
BOEING

9P237000 - 15
4/13/99/BF

Delta Payload Planning Information

Mission planning information available from multiple sources

Payload Planners Guides



Delta Web Page

http://www.boeing.com/defense--space/space/delta/delta2/guide/
http://www.boeing.com/defense--space/space/delta/delta3/guide/
http://www.boeing.com/defense--space/space/delta/delta4/guide/

Contact Delta Launch Services (714) 896-4321

BOEING

9P237000 - 16
4/13/99/BF

Backup

Delta Secondary Payload Missions History

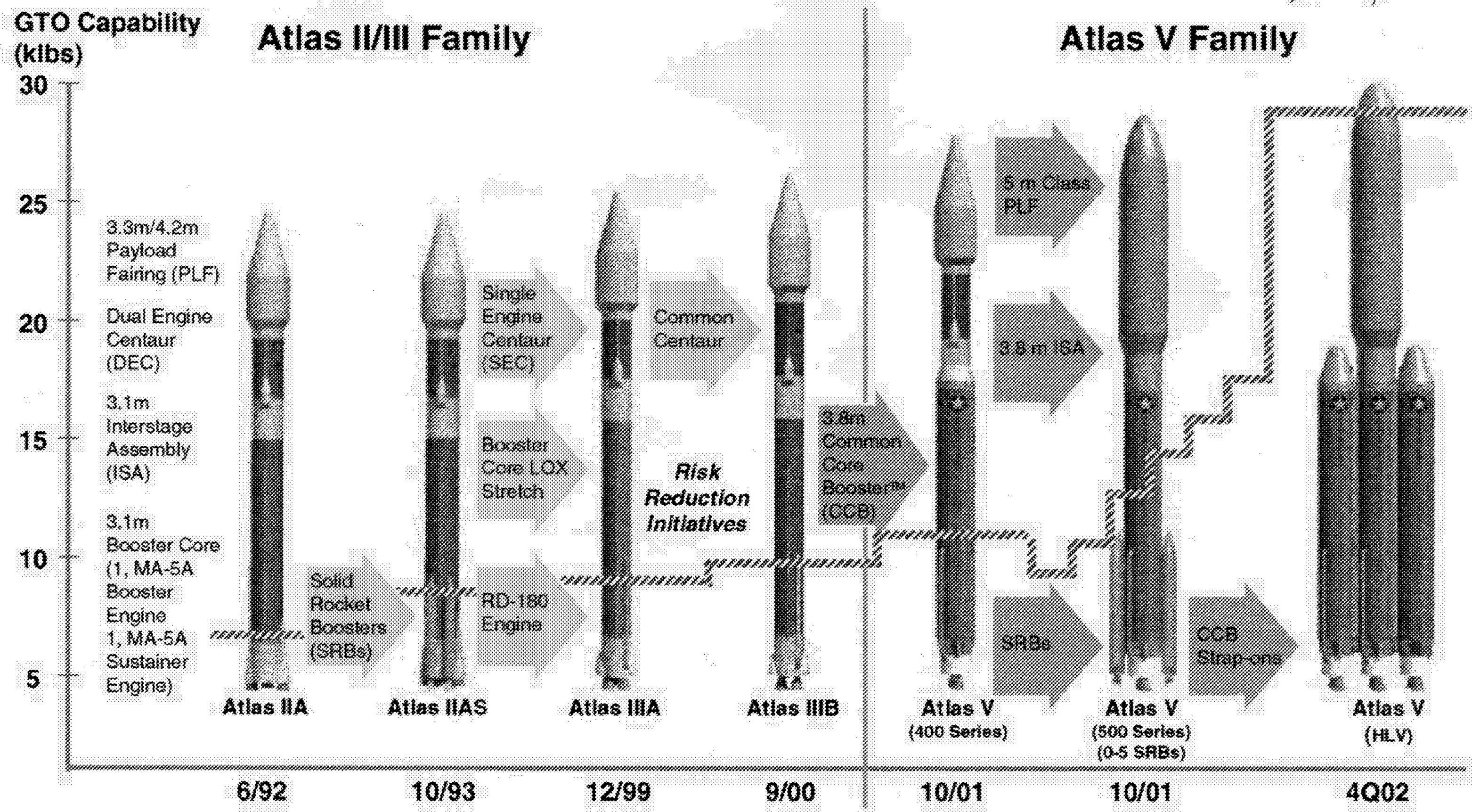
Delta No.	Mission	Secondary	Launch Date
55	Pioneer-C	TTS; Cal-NCE	12-13-67
56	GEOS-B	Cal-NCE	01-11-68
60	Pioneer-D	TTS	11-08-68
72	OSO-G	PAC	08-09-69
76	TIROS-M	OSCAR	01-23-70
86	0S0-H	TUR	09-29-71
91	ITOS-D	OSCAR	10-15-72
104	ITOS-G	OSCAR, INTASAT	11-15-74
139	Landsat-C	OSCAR, PIX	03-05-78
145	Nimbus G	Cameo	10-24-78
157	SME	UOSAT-A	10-06-81
166	IRAS	PIX II	01-25-83
174	Landsat-D	UOSAT-B	03-01-84
206	Navstar 11-11	LOSAT-X	07-03-91
212	Geotail	DUVE	07-24-92
219	GPS-1	SEDS-1	03-29-93
221	GPS-3	PMG	06-26-93
226	GPS-6	SEDS-2	03-09-94
229	RADARSAT	SURFSAT	11-04-95
261	Deep Space 1	SEDSAT	10-24-98
267	P91-1 ARGOS	Oersted Sunsat	02-23-99

BOEING

9P237000 - 18
4/13/99/BF

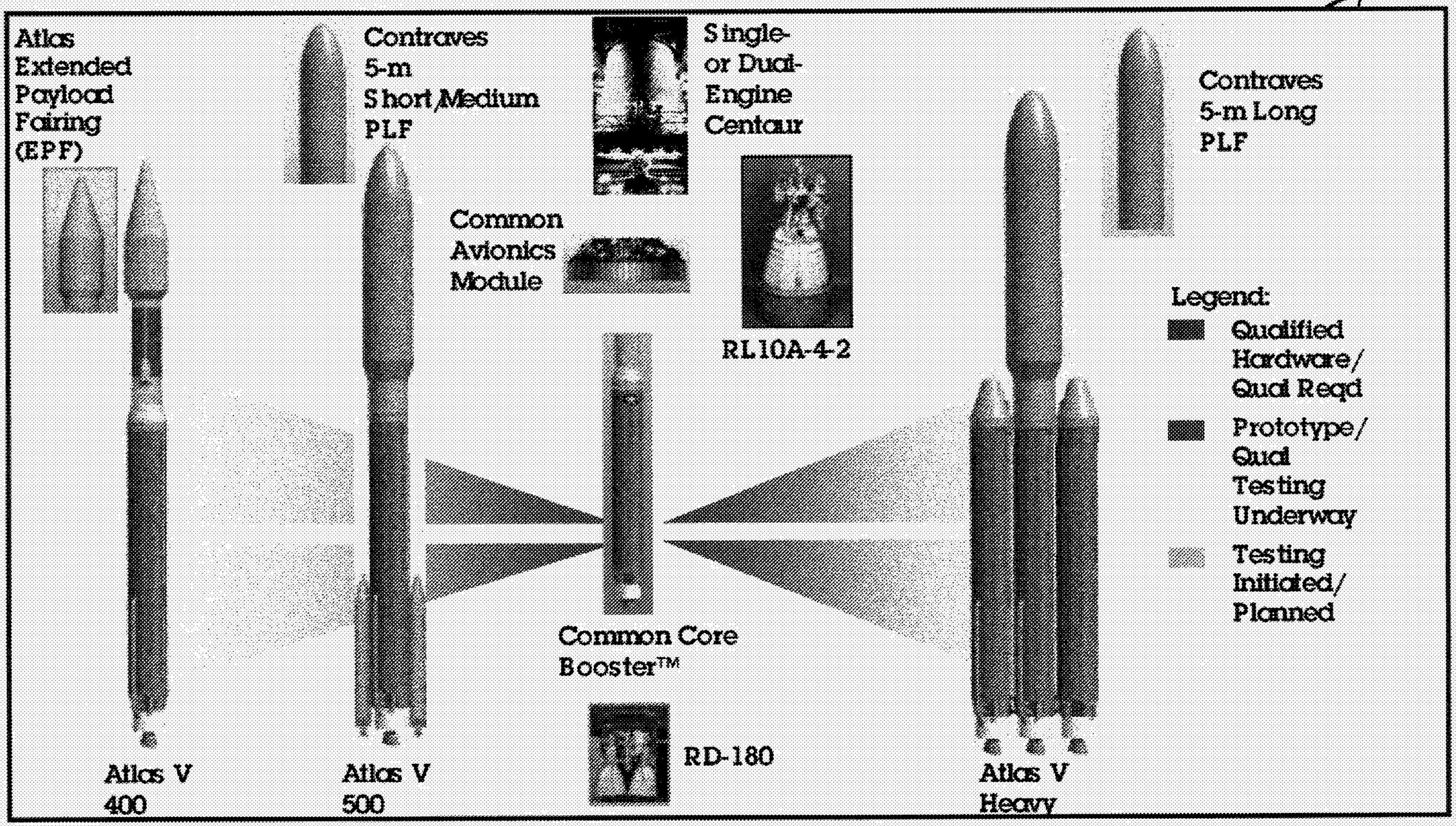

Atlas V
LOCKHEED MARTIN

Atlas Evolution

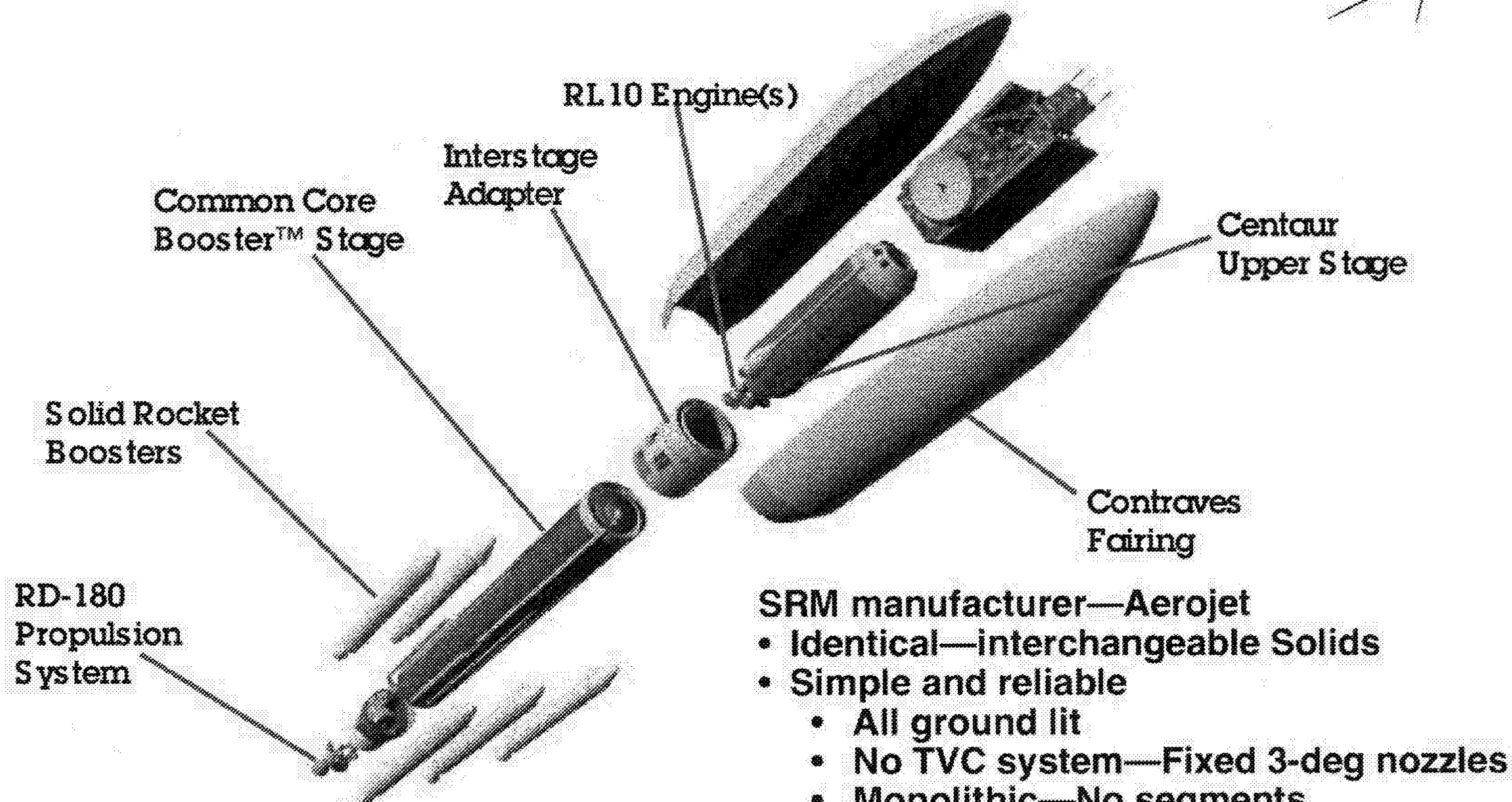


Continually improving value for our customers.

Atlas V Common Element Concept



Atlas V (552) Launch System



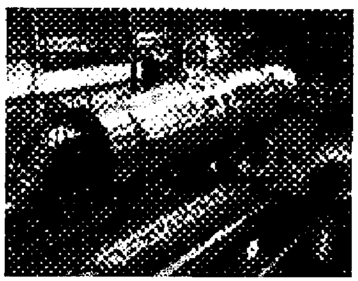
SRM manufacturer—Aerojet
- Identical—interchangeable Solids
- Simple and reliable
  - All ground lit
  - No TVC system—Fixed 3-deg nozzles
  - Monolithic—No segments
- Ship and shoot

Maximum Mission Flexibility
One - Five SRMs Provide- GTO: 9-19k lbm, LEO: 24-40k lbm

Hardware Development Progress

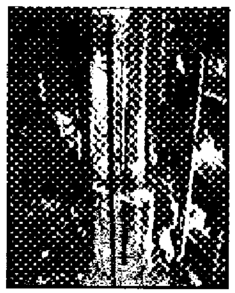

RD-180 Engine
Final Assembly Building


Atlas V Tank Dome


Atlas V Tank in AWC



Atlas III Stage
Test at
NASA/MSFC

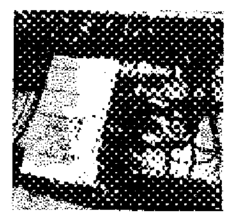

Atlas V
Tank in VTF

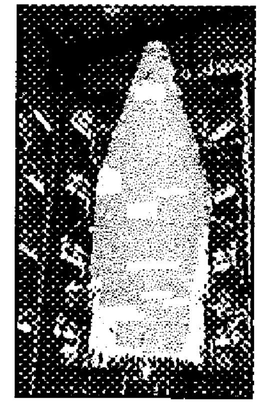

Atlas V
Tank in ARL

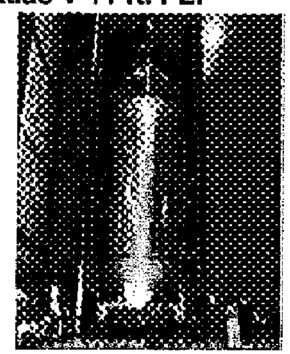

Contraves 5-m PLF


Single Engine Centaur
Final Assembly Building


Honeywell
Fault-Tolerant INU

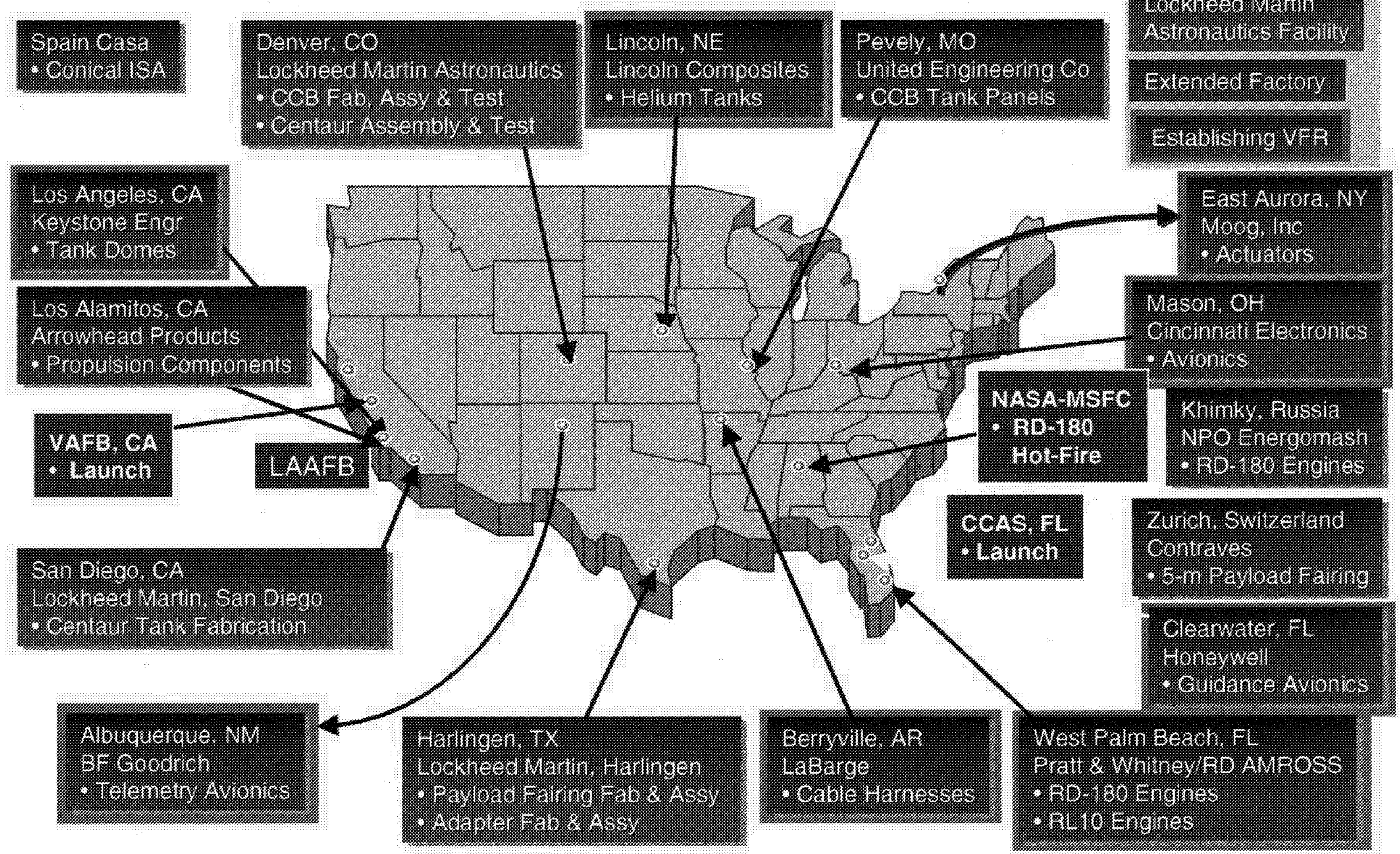

BF Goodrich Data
Acquisition System


Atlas V 11 ft. PLF


Atlas V Tank
in VTF

Atlas V is accomplishing key development milestones

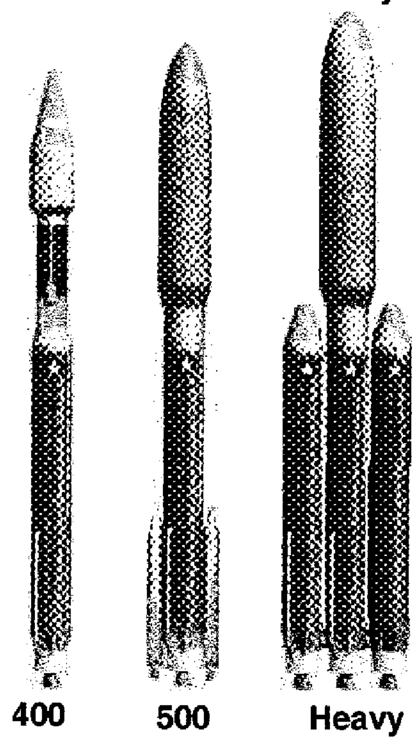
Atlas V Participating Locations



Atlas V Tailored Critical Design Review Summary

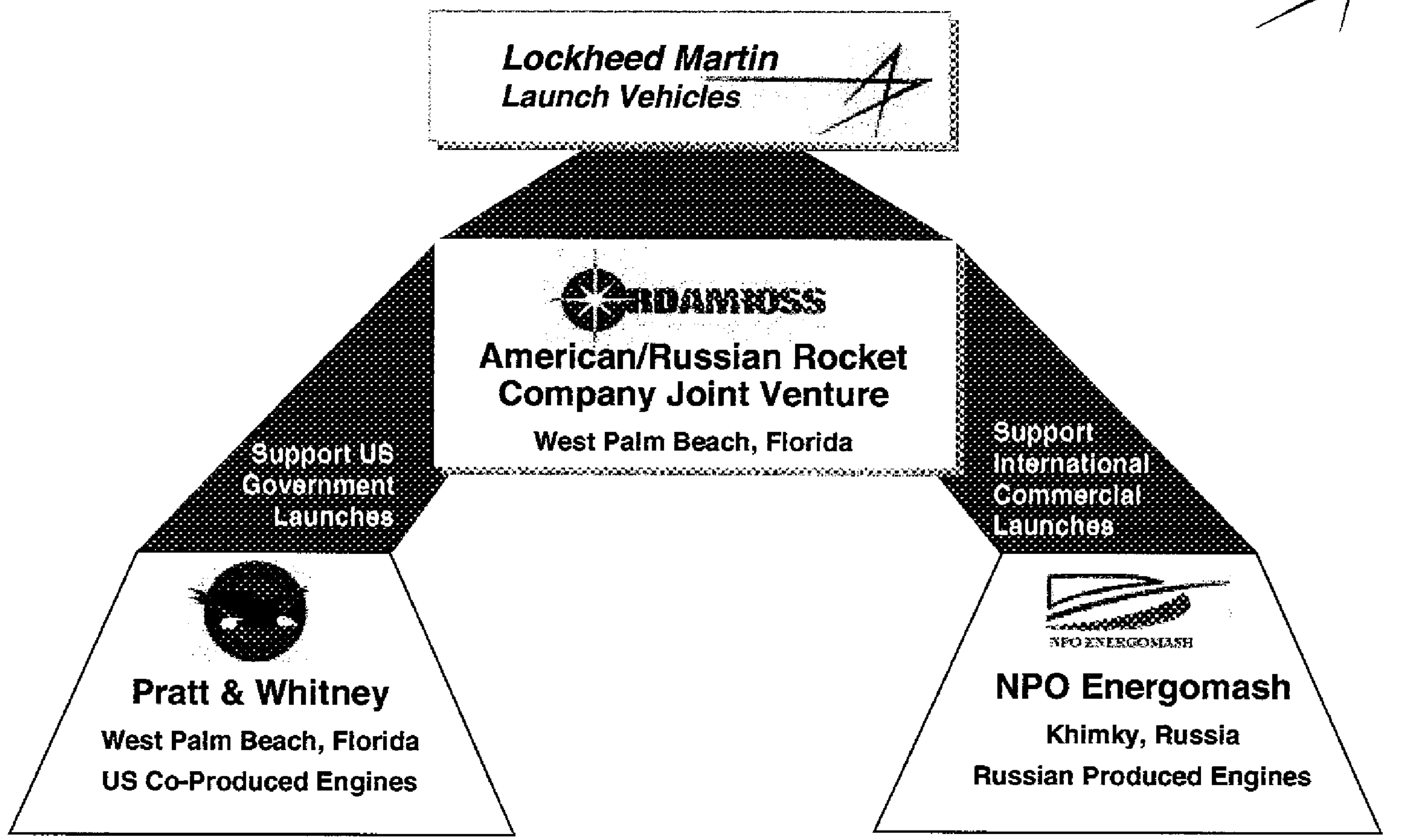
- Series of 12 reviews—4 vehicles and 2 pads
- 34 review days—May 18-July 29
- 8,107 briefing charts in addition to supporting materials
- TCDR Preceded by Several Months of Detailed Subsystem Briefings

Atlas V
Launch Vehicle Family



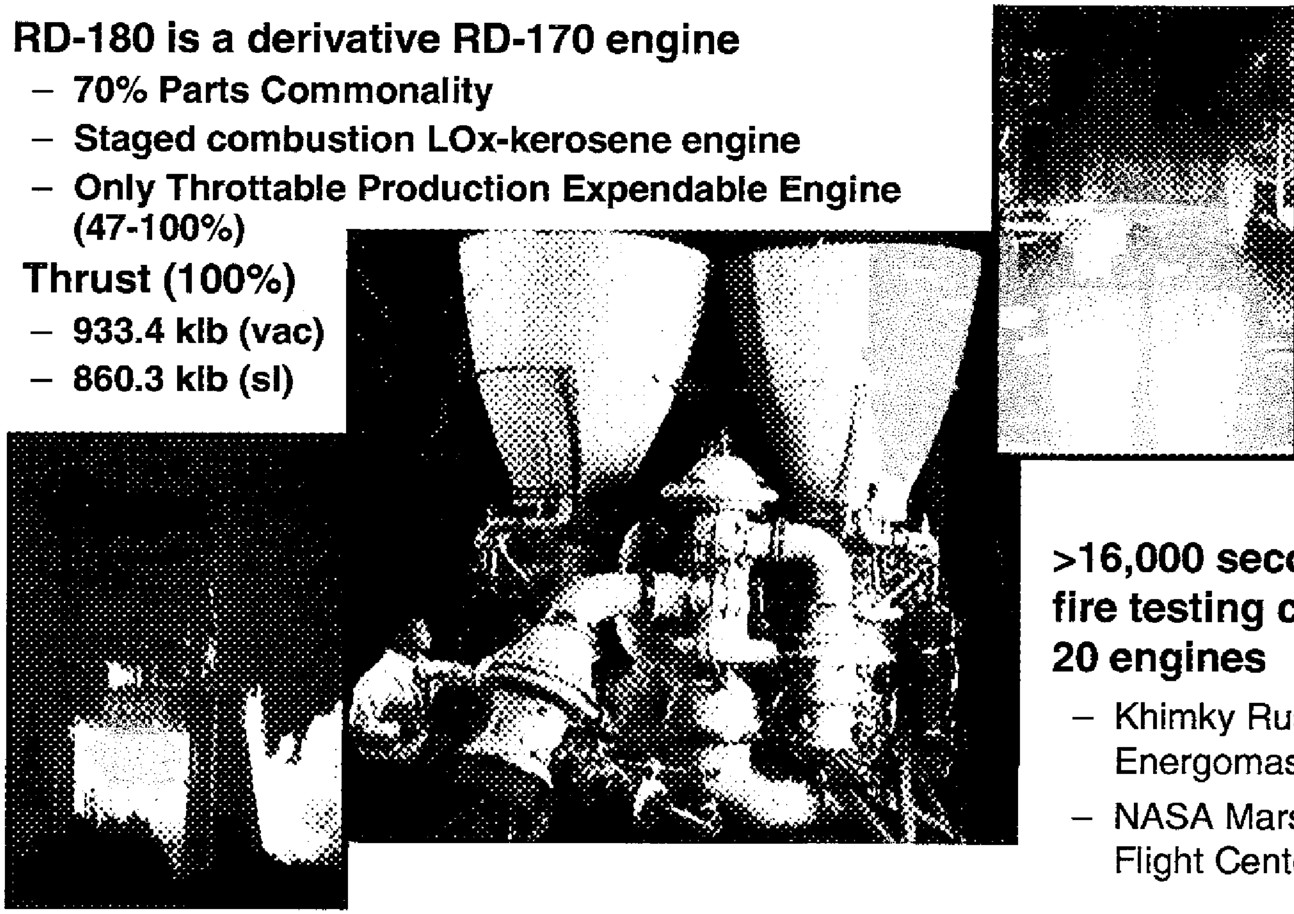
TCDR judged as "Excellent" by the Customer and Independent Review Panels

RD-180 Engine Team



RD-180 Update

- **RD-180 is a derivative RD-170 engine**
  - **70% Parts Commonality**
  - **Staged combustion LOx-kerosene engine**
  - **Only Throttable Production Expendable Engine (47-100%)**
- **Thrust (100%)**
  - **933.4 klb (vac)**
  - **860.3 klb (sl)**

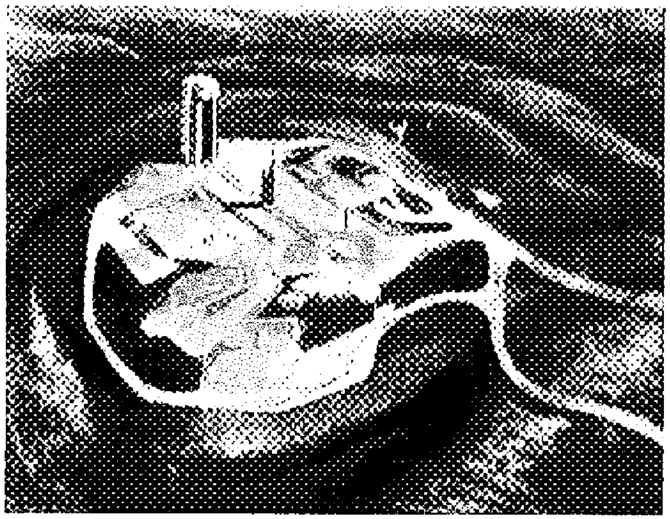


>16,000 seconds of hot fire testing completed on 20 engines
- Khimky Russia at NPO Energomash
- NASA Marshall Space Flight Center

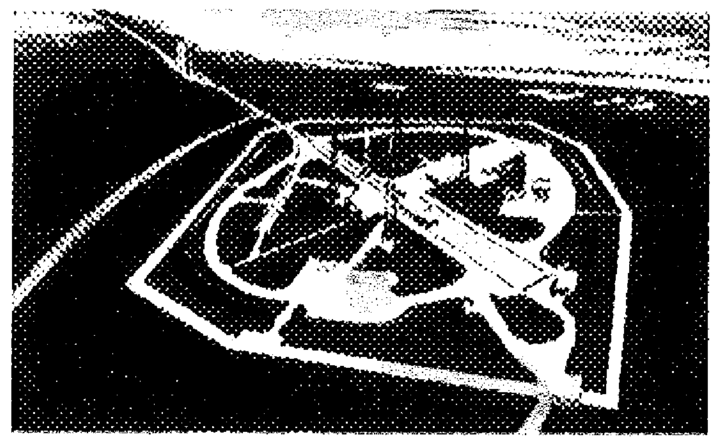
The RD-180 Engine Is Certified For Flight

Common Operational Concept

- Features
  - Common Concept at LC-41 and SLC-3W
  - Common Procedures and Equipment at CCAS and VAFB
    - Minimum Time on Pad
    - Common Processing for All Vehicle Configurations
  - Full Weather Protection in VIF

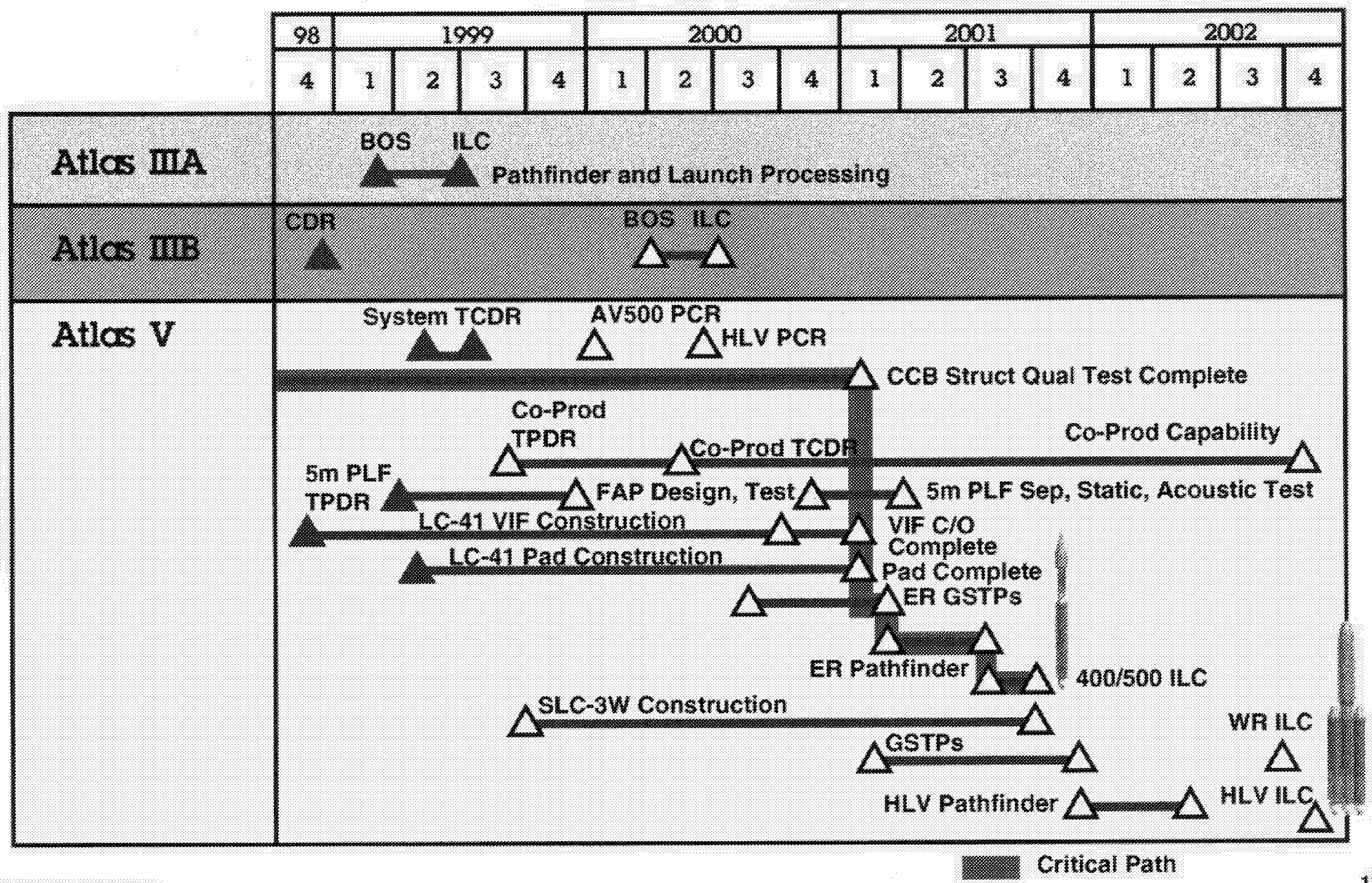


SLC-3W at VAFB

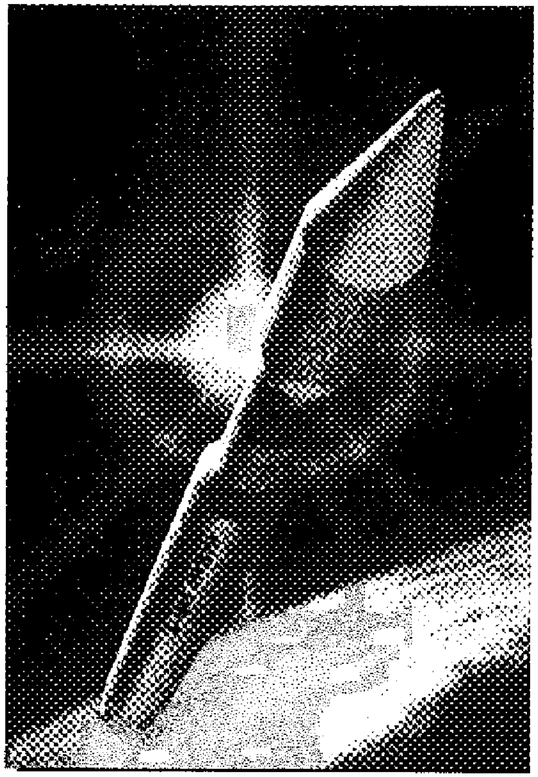


LC-41 at CCAS

Atlas V Development Schedule



Summary



- Low Risk, Heritage Design
- Standard Payload Interfaces
- High Performance Within Each Vehicle Class
- 4 and 5 meter Payload Fairings
- Modular, Common Element Design
- High Launch Rate
- Efficient Operations
- Commitment to Mission Success

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 1999	Conference Publication

4. TITLE AND SUBTITLE
Proceedings of the First Annual NRO-OSL/GSFC-ATS Rideshare Conference—April 15–16, 1999

5. FUNDING NUMBERS
740.2

6. AUTHOR(S)
W. Cutlip, Ed.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS (ES)
Mission Integration and Planning Division
Project Formulation Office
Goddard Space Flight Center
Greenbelt, Maryland 20771

8. PEFORMING ORGANIZATION REPORT NUMBER
99A01867

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS (ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
CP—1999–209482

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Unclassified–Unlimited
Subject Category: 15
Report available from the NASA Center for AeroSpace Information, 7121 Standard Drive, Hanover, MD 21076-1320. (301) 621-0390.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This document contains the proceedings of the First Annual NRO-OSL/GSFC-ATS Rideshare Conference. The conference was held April 15–16, 1999, at the Litton/TASC Facility, Dulles, Virginia. and was co-chaired by William Cutlip, Goddard Space Flight Center Access to Space Group, and Jim Liller, National Reconnaissance Office, Office of Space Launch.

14. SUBJECT TERMS
Rideshare; space transportation; buses; Get Away Special (GAS), launch vehicle.

15. NUMBER OF PAGES
550

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL